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OPERATIONS PROFILES
FOR
LUNAR ROVING MISSIONS

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FOREWORD

The investigations documented in this report constitute a part of the Lunar Roving Vehicle (LRV) research conducted by the Advanced Lunar Studies (ALS) team at the Jet Propulsion Laboratory.* These investigations in the field of Mission Operations have been performed to develop and provide for LRV the background of practical related information necessary prior to the initiation of a new project in a hitherto unexplored field.

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ABSTRACT

This report describes preliminary Mission Operations analyses of:

(1) The sequence of operations needed to execute those individual elemental tasks which, in recurrent combination, form the Operational Profile of the Lunar Roving Vehicle Mission.

(2) The functional requirements which such elemental tasks impose upon the Mission Operations Complex.

CONTENTS

*Sections 2.0 and 7.0 are intentionally omitted.

I. INTRODUCTION

A. BACKGROUND

In the design of space missions, it is customary to begin by identifying the total chain of primary activities to be undertaken. In the case of the LRV, however, the specific mission to be undertaken (i. e., the particular route to be followed, places at which to stop, and science operations to be conducted) is not presently known and will ultimately be selected from knowledge of the vehicle's operational capabilities, as well as the opportunities for exploration which the moon presents. The present study has been directed toward the identification and description of the family of modular operational routines which are inherent in a remotely controlled Lunar Roving Mission and could be embodied in a set of LRV mission profiles. Once adopted, such modular routines prove useful in both the planning and the execution aspects of the mission. The ultimate mission will consist of a sequential combination of such modular routines, with repetition occurring as necessary.

The selection of particular operational modules (termed "modes" in this report) is necessarily somewhat arbitrary. The philosophy which has guided the selection of the modes shown has been that of practical utility in achieving specified objectives with the minimum number of modes. Reduction in the scope assigned to any given mode would reduce the number of subsets of operational routine for that particular mode but would also increase the total number of modes which must be considered in concert to achieve any given objective.

The present report covers the second phase of a continuing study of LRV mission operations problems at JPL. The body of the report deals with two planning properties of the operational modes. These are (a) the logical sequence of activities required and (b) the ground systems support required.

Because of the developmental character of the LRV study, the present document is not a final report upon a closed topic but is, instead, a status report upon an expanding topic. Continuing investigations are studying systematically the next logical operational factors to be defined, as described in Section I-D. Later, definitive missions (specified routes, specified stopping-places, specified science activities), consisting of linking modular sets of

operations into a total operational profile, can be evaluated with regard to resources (time, power, and other requirements).

This report has three useful aspects:

(1) The results of this study constitute a foundation for future LRV mission operations investigations. Time studies, power profile analyses, data handling analyses, route planning, and Mission Operations Complex (MOC) design are dependent upon prior establishment of the unit operations to be undertaken.

(2) The optionally exercisable sequences of mission operations identified in this report provide a means for adapting the mission to the circumstances encountered.

(3) The report identifies subjects in the area of mission operations which need to be investigated further.

B. PRIOR STUDIES OF LRV MISSION OPERATIONS

Previous (Phase A) studies of LRV operations (Refs. 1 and 2) identified the major elements and functions required to support LRV missions. These preliminary studies considered the potential range of equipment on the LRV, principal functions to be performed, and appropriate structure of the ground support system.

The earlier (Phase A) studies differed from the present (Phase B) studies in two ways:

(1) The principal operations functions (navigation/guidance and science) were considered separately, without integration. Matters concerning navigation and guidance were reported in Ref. 1, matters concerning science in Ref. 2.

(2) The vehicular equipment for navigation and guidance was considered separately for each of four possible levels of automation.

C. PRESENT STUDY OF LRV MISSION OPERATIONS

The present (Phase B) report continues the study of LRV mission operations; narrowing the range of possible equipment for navigation and guidance

down to a single set, updating the assumed list of scientific instruments, establishing operations modes, outlining operational profiles within such modes, and identifying the ground system functions needed.

II. PURPOSE AND SCOPE

A. PURPOSE OF STUDY

The purpose of this study is to provide improved understanding and visibility into the LRV operations.

Specific goals are to define:

(1) Modular sequences of activities (modes) which can be treated as blocks of operations, both during the planning phase and in the operations phase of the LRV mission, and which provide a convenient tool for studying a mission whose total profile is not yet known.

(2) Preliminary operational requirements upon the MOC for the LRV mission.

B. SCOPE OF STUDY

(1) Mission Phase.

This study concerns only the remotely-controlled surface exploration portion of the mission.

(2) Vehicle.

One single vehicle design is considered. This is the Phase B Baseline for the LRV mission as described in Section III.

(3) MOC Elements.

This study describes, in preliminary fashion, the operations profiles and ground system requirements for daytime operation of the LRV mission.

(4) Real-Time Operations.

Identified, in a systems approach, are the interlaced relationship between lunar and ground (terrestrial) operations that exist in real-time execution of the mission. Non-real-time ground activities (those not influencing variation in the execution of subsequent lunar operations) are identified only for completeness.

(5) Standard-Condition Operations.

Because these studies are preliminary in nature, an effort has been made to limit the operations considered to those which are involved in straight-forward, trouble-free execution of a planned (nominal) mission.

(6) Excluded Functions.

The present study does not include detailed considerations of:

(a) Mission-independent ground operations.

(b) Placement of deployable, stationary scientific-instrument packages, e.g., Remote Geophysical Monitors (RGM's).

(c) Lunar-nighttime operations.

(d) Changeovers from lunar nighttime operations to lunar daytime operations.

III. INTERIM MISSION DESCRIPTION

A. PURPOSE AND SCOPE OF MISSION

In a pre-project study, the system designs cannot be known until the study is completed. In the meantime, advances in one portion of the design must be predicated upon interim descriptions of the significant interactive features of all other parts of the design. Such an interim description for the purpose of enabling trade-off studies is termed herein the "Baseline."

The Baseline presented for this study is the Phase B[1] Baseline for the LRV Mission. It includes identification of the following mission-elements:

(1) Mission description (Part B in this section)

(2) Lunar equipment (Part C)

(3) Science experiments (Part D)

B. MISSION DESCRIPTION

1. Mission Goals and Objectives

The goals and objectives of the LRV family of missions were presented in Refs. 1 and 2 as follows:

(1) Scientific exploration of the moon.

(2) Lunar technology development.

(3) Extension of man's domain to the moon.

Detailed objectives within these goals are outlined in Tables 1, 2, and 3.

2. Assumed Mission Scope

(1) The LRV will be operated unmanned, by remote-control.

(2) The missions considered to date are almost exclusively of a geological character.

(3) Any or all of the operational modes described in Section VI hereof may be called upon.

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[1] Derived during JPL Phase B LRV studies.

Table 1. LRV Mission Goal (A) Support Scientific Exploration of the Moon

- Moon's origin, age and history
- Origin of life
- Evolution of Earth-Moon system and the solar system

OBJECTIVES

(I)	Determine character of major classes of lunar surface features and surface processes, and resolve regional problems.
(II)	Sample lunar materials, and determine rock identification and elemental, isotopic, chemical, and mineralogical composition.
(III)	Determine gross structure, processes, and energy budget of lunar interior.
(IV)	Moon-wide and regional control of lunar surface by metric and high resolution orbital photography and remote sensing coverage.
(V)	Determine near-moon environment: Fields and particles.
(VI)	Determine organic composition of lunar materials and presence of biological materials.
(VII)	Determine geological processes sculpting the lunar surface.

Table 2. LRV Mission Goal (B): Support Lunar Technology Development

- Capability for lunar surface operations over extended distances
- Communication capability point-to-point and from far side
- Reduction in astronaut hazards

OBJECTIVES

(I)	Capability for long-range operations with surface vehicles during both day and night.
(II)	Support capability for lunar operations, e.g., power, communication, data processing, ground operations.
(III)	Minimize problems and risks of long-term survival by reliable rescue and escape.
(IV)	Procedures and testing systems for rovers in planetary exploration.

Table 3. LRV Mission Goal (C): Support Extension of Man's Domain to the Moon

- Reduce man's dependence on earth by use of lunar resources
- Capability for man's useful work on moon over extended periods

OBJECTIVES

(I) Locate lunar resources useful for:

Life support

Power

Propellants

Construction

Earth's economy

(II) Determine whether man can function as a planetary explorer and space engineer.

(4) The LRV is expected to be operated continuously and at the highest possible level of scientific productivity except when halt is required for battery recharge, alleviation of over-heating, or diagnosis of critical problems.

(5) Tracking by both laser and RF is envisioned.

(6) No orbital support during the mission is assumed.

3. Mission Constraints

Mission constraints now recognized include:

(1) Movement of the LRV is restricted to the near-earth face of the moon (because of tracking and data acquisition considerations).

(2) Primary reduction of scientific data is to be performed on a real-time basis (since it is needed for mission control).

(3) 24-hour-a-day continuous LRV operations and ground support are required (to maximize the effectiveness of the mission).

(4) Lunar night-time operations are desirable to maximize the effectiveness of the mission.

(5) Maximum advantage shall be taken of scientific opportunities encountered (within resource limitations).

(6) The uncertainty[2] in the estimated value of each of the six coordinates of selenographic position (latitude, longitude, gravipotential elevation, bearing, pitch, and roll) must be kept within the tolerances specified for science purposes.

C. LUNAR EQUIPMENT

1. Introduction

The equipment of the LRV on the moon is considered here to be divided into three distinguishable systems:

(1) The Navigation/Guidance System, which performs all on-board functions related to
  - (a) Determination of position
  - (b) Obstacle detection and avoidance
  - (c) Motion control

(2) The Science System, which performs all on-board functions related to the execution of science experiments.

(3) The Vehicle System, which performs all on-board functions related to:
  - (a) Mobility
  - (b) Communications and data handling
  - (c) Power generation
  - (d) Thermal control
  - (e) Mechanism control
  - (f) Diagnostics

A description of the equipment currently envisioned for each of these on-board systems is presented below.

[2] Total of all known contributions to error.

2. LRV Navigation/Guidance System

a. General

The functional block diagram of the single Navigation/Guidance System synthesized from the four candidate navigation/guidance systems (Ref. 1) is presented in Fig. 1. The total Navigation /Guidance System can be considered to consist of a navigation subsystem and a guidance subsystem. These subsystems are described below in paragraphs b and c. The selected system is intermediate in complexity among the four defined in Ref. 1. It does involve the use of near-real-time TV by the ground operator for driving the vehicle.

b. Navigation Subsystem

Primary Navigation. The primary navigation subsystem performs a dead reckoning function and consists of three main groups constructed from basic available equipment.

A "fully compensated," cageable, directional gyro senses angular deflections about pitch and yaw axes (from initial setting) in a forward vehicle coordinate system. A "fully compensated" gyro provides for the elimination, via on-board closed loop, of errors due to variation from local vertical (i. e., vehicle motion) and the elimination, via closed loop through ground, of errors due to the rotation of moon, bias, and mechanical imbalance and friction (predictable drift).

Inclinometers and accelerometers - two each per vehicle section - sense pitch and roll (with respect to local lunar vertical) of each vehicle section.

Odometric sensing occurs by wheel rev/min determination via count of wheelmotor current pulses occurring per unit time. There is one wheel motor per each of six wheels.

Update Navigation. The update navigation subsystem is based on landmark identification via FAX panorama. Bearings to landmarks are used for position fixing and heading determination of vehicle. A high resolution TV is provided for better identification of landmarks.

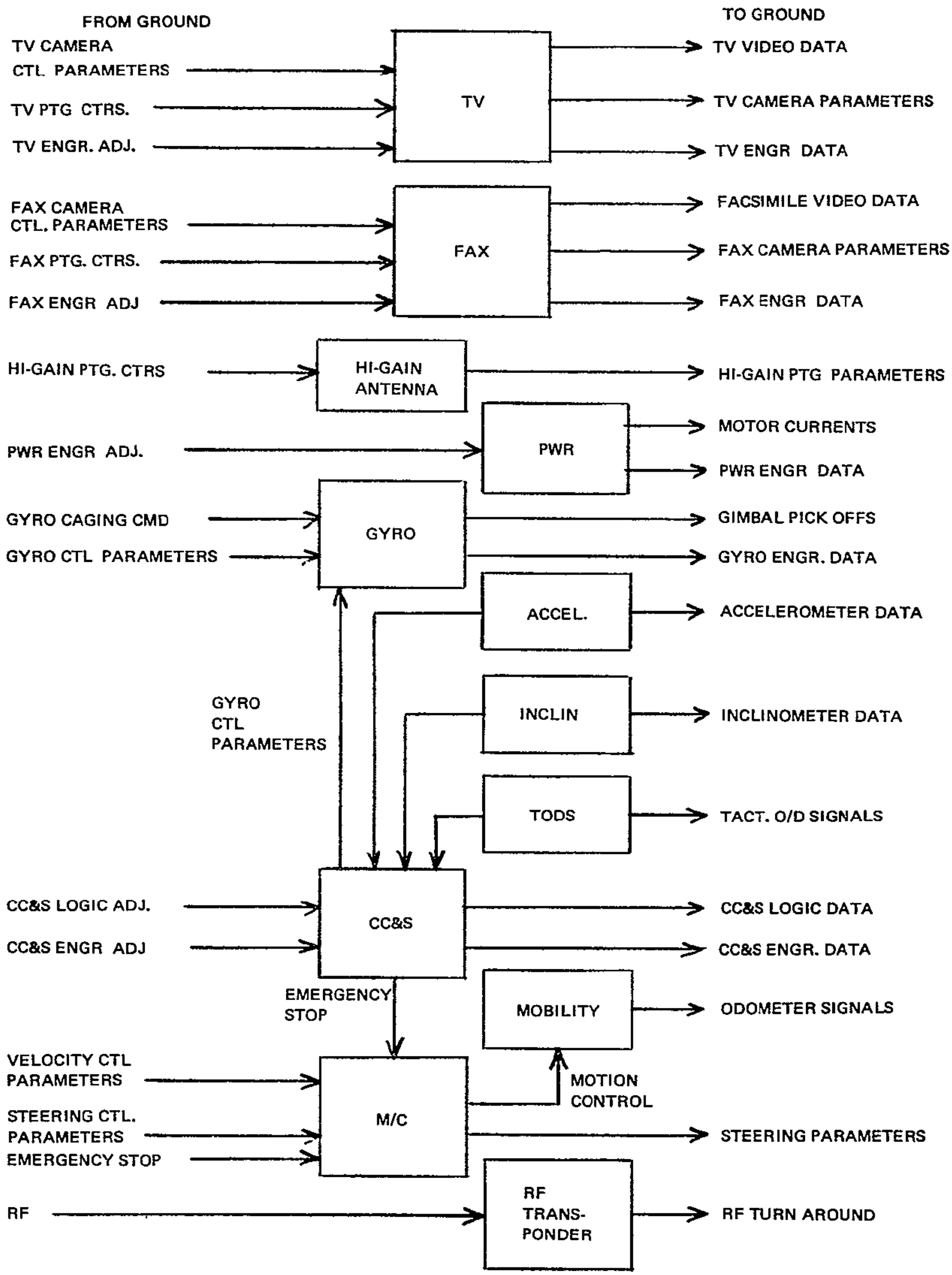

Fig. 1. LRV Baseline Functional Block Diagram Automated Configuration

Backup is provided by a differential range and doppler with RF transponder on LRV, ALSEP (or equivalent), and RGMs. In areas without recognizable landmarks, backup may be provided by celestial navigation (including use of shadow lines) via TV and/or establishing (a) bearings to the center lines of craters and (b) angles subtended by the craters.

D. GUIDANCE SUBSYSTEM

Obstacle Detection. Subsystem provisions for obstacle detection are:

(1) TV (real-time) without image stabilization (neither electronic nor mechanical) with a 1 frame/sec transmission rate to earth and a 500 line scan per frame. Exposure time is on the order of milliseconds.
(2) Tactile Obstacle Detection Subsystem (TODS) consisting of passive devices, which, upon physical contact with an obstacle, would initiate an automatic vehicle stop.
(3) Navigation and guidance instrument data from accelerometers, inclinometers, motor current ammeters, directional gyro, and odometers.

Obstacle Avoidance. Subsystem provisions for obstacle avoidance are:

(1) Automatic stop generated on-board when TODS or NGIP indicate transgression of a hazard threshold.
(2) Ground backup computation of GO/NO-GO signals.
(3) Remote-controlled steering and/or velocity control to maneuver around obstacles.

Motion Control. Subsystem provisions for motion control are:

(1) Steering with an automatic steering control mode which maintains heading via closed-loop through ground and a manual steering control override via joystick with an automatic reversion to proper heading.
(2) Automatic velocity control computes on-ground an optimum speed from all required inputs with provisions for manual velocity control overrides via joystick.

3. LRV Science System

a. Science Instruments on LRV

A baseline list of science instruments is presented in Table 4. This list has purposely been made large in order that experiment operation requirements would be brought out by the study. The functions of these instruments are described in Ref. 2 (Appendix D) except for instruments numbers iv, vi, xiii, xiv, and xxii whose functions are described in Appendix D of this report.

b. Science Equipment (Non-Instrumental)

On-board equipment (other than science observational instruments) to support science experiments includes:

(1) Power Conditioning
(2) Thermal Conditioning
(3) Data Storage and Processing
(4) Diagnostic Observing Equipment

c. Earth-Based Science Instruments

In addition to on-board equipment, the gravimetry experiment requires a system of earth-based laser tracking stations. The functions of these tracking stations are described in Ref. 2 (Appendix D) under the heading "Earth-Distance-Ranging."

4. LRV Vehicle Design

The design of the vehicle system is not a primary consideration within this report. It is appropriate, however, to identify those factors within the presumed design which impact upon or influence mission operations. The assumed design is based on results of two studies of the Dual-Mode Lunar

Table 4. Science Instruments Assumed to be on LRV

1. Panoramic (facsimile) camera (with vertical stereo capability)
2. Terrain assessment (TV) camera (with horizontal stereo capability)
3. Closeup (TV) camera (with zoom lens)
4. General purpose manipulator (two, deployable)
5. Sampling scoop bucket (deployable)
6. Sample cup holder (transportable by manipulator)
7. Rock chipper (transportable by manipulator)
8. Rock tongs (transportable by manipulator)
9. Rock core drill (deployable)
10. Brush or grinding wheel
11. Sample storage and handling device (with buffer)
12. X-Ray diffractometer
13. X-Ray spectrometer
14. Atmospheric mass spectrometer
15. Neutron gamma-ray analyzer* (deployable)
16. Vector magnetometer (deployable)
17. Laser gravimeter (deployable)
18. Seismic sensor (deployable)
19. Seismic charges (deployable)
20. Seismic charge emplacer
21. Seismic detonator
22. Remote geophysical monitors (3, each including laser retroreflector and passive seismometer)
23. Laser radar (scanning laser range-finder)

*Abbreviated in the report as "NGRA".

Roving Vehicle (DLRV) (Refs. 4 and 5). The significant subsystems are the following:

(1) Power Subsystem

(2) Communications Subsystem

(3) Thermal Control Subsystem

In addition it is assumed that the vehicle has night-time mobility.

IV. GUIDELINES AND ASSUMPTIONS OF THE STUDY

A. GUIDELINES

(1) Inference of the use of a particular Tracking-and-Data-Acquisition system was to be avoided.

(2) Operations within mission-independent facilities were not to be detailed.

(3) Non-standard operational conditions were not to be studied.

(4) The charts and diagrams presented were to show the logical sequence of operations (not necessarily the flow of data).

(5) The choice of groupings of operations were to consider both the efficiency of operations and the retention of flexibility during the mission.

B. ASSUMPTIONS

Only broad assumptions are treated here. Assumptions peculiar to individual operational modes are presented at the description of such modes.

1. Mission-Related Assumptions

(1) The mission objectives, scope, and description are as described in Section III-A and III-B of this report.

(2) Round-the-clock operations are assumed. Any reduction in rate of progress created by interruption, delay, or slowing of lunar operations due to ground support facility limitations reduces the rate of scientific data return and hence degrades mission achievement.

(3) The Mission Operations Plan, describing all activities to be undertaken under standard conditions, is complete prior to beginning of mission.

2. Vehicle-Related Assumptions

(1) The vehicle conditions are as described in Section III-C of this report.

(2) The command receiver on the vehicle is continuously capable of receiving and executing commands from earth.

(3) RGM's deployed from the vehicle are not connected in any way to the vehicle after deployment.

(4) No constraints exist upon the sequence in which deployed science packages must be retrieved.

3. <u>Other Assumptions</u>

(1) The total activities during execution of the mission can be considered to consist of three concurrent types:

(a) Continuous on-going activities not requiring stop-and-start.

(b) Operational sequences for individual objectives.

(c) Decision-making to adapt the pre-mission plan of operations to conditions actually encountered to satisfy new constraints and exploit new opportunities.

(2) Laser earth-distance ranging is a mission-independent operation.

(3) TV pictures can be transmitted and displayed fast enough not to constrain operations.

(4) Unless otherwise specified, all operations are in lunar daytime.

V. INVESTIGATIVE APPROACH

A. OUTLINE

The approach taken in developing the operations profiles for the LRV mission involved four basic steps:

(1) Though no specific traverse route has been selected, the elemental tasks which will comprise any such mission are known to be inherently recurrent.

(2) The elemental recurrent tasks were identified.

(3) The logical sequence of activities for each recurrent task was developed.

(4) The functional requirements upon the ground support system, MOC, necessary to implement each detailed activity were analyzed.

B. OPERATIONAL TASK TYPES

Prior studies (Refs. 1 and 2) have shown that the LRV Mission will consist of a series of tasks of the following types:

(1) Scientific investigations (chiefly geological) must be conducted at specified sites.

(2) Scientific investigations must be conducted while the vehicle is in motion.

(3) RGM's must be deployed and checked out.

(4) The vehicle must be steered safely in traversing from site to site.

(5) The position of the vehicle with respect to reference selenographic coordinates (including elevation) must be determined to within specified accuracy.

(6) The vehicle must be maintained in suitable condition to satisfactorily perform its future functions throughout the remainder of the mission.

(7) Scientific opportunities which are encountered should be exploited in an optimum manner consistent with the resources available.

C. DEVELOPMENT OF OPERATIONAL MODES

The basis used for subdividing operations was to provide units associated with the achievement of clearly identified goals. The first or top level units (the largest groupings of standardized activities) are termed here "operational modes" or simply "modes." Subdivisions of these operational modes are termed "major sequences" and a further order of subdivision yields "minor sequences."

This segmentation of the total mission into levels of operational activity results in the following hierarchy:

(1) Mission
(2) Phase
(3) Mode
(4) Major Sequence
(5) Minor Sequence

By assumption, items (1) and (2) were set for this study. The three remaining routines, (3), (4) and (5), are the concern of this report

It is noteworthy that each operational routine is characterized by a particular set of objectives and each operational routine connotes temporary dominance of a particular organizational routine or function.

The two chief criteria in establishing operational modes and sequences are: 1) simplification and efficiency of operations through the use of nominally standard operational modes and 2) retention of flexibility (ability to depart from standard or nominal procedures when necessary). Consideration must also be given to the fact that a change in operating mode is generally accompanied by a change in the configuration of lunar equipment, ground equipment, and/or personnel and that various modes may be used recurrently or repetitively.

D. PRINCIPAL OPERATIONAL MODES

Early steps to resolve the total lunar activities into a minimal number of discrete standardized operational modes showed a number of important interrelations between the several tasks listed above (paragraph B). First, from Phase A studies, the scientific investigations to be conducted along the traverses

were found to be chiefly stationary, i. e., their execution required that the vehicle be halted. Second, the scientific investigations to be conducted at primary science sites would normally require stationary operations to be performed at a chain of stations within the area of the site. Third, the science activities, when halted at a primary science site, were identical with those at halting points along the traverses connecting primary science sites. The exceptions were the Active Seismic experiment and RGM placement. Last, the successful accomplishment of a traverse requires the joint execution of tasks 2, 4, 5 and 6 of Paragraph V-B. These considerations led to the initial choice of seven standard operational modes:

(1) Traverse Mode
(2) Navigation Update Mode
(3) Stationary Science Mode
(4) Active Seismic Mode
(5) RGM Deployment Mode
(6) Quiescent Mode
(7) Major Diagnostic Checkout Mode

These modes are described in detail in Sections VI and VII of this report.

E. DIURNAL CYCLING MODES

The long life assumed for the LRV, extending through many cycles of lunar day and lunar night, required additional modes to supplement those identified above.

Night-time use of the LRV would be enabled by three additional modes:

(1) Night Traverse Mode
(2) Night Navigation Update Mode
(3) Night Stationary Science Mode

With this addition, the corresponding earlier modes (D-(1), D-(2) and D-(3)) became designated as Day Modes. Accommodation of the change from daytime conditions to nighttime conditions required two further modes:

(4) Sunset Preparation Mode
(5) Sunrise Preparation Mode

This set of five modes related to nighttime operations is identified in Section VI of this report, but is not treated in detail in Section VII.

F. OPERATIONAL PROFILES

The next step in the analysis of the operational modes was to identify, within each mode, the logical ordering of the groups of operations (major sequences) required to achieve the goals of that particular mode. The major and minor sequences for each mode are presented diagramatically in Section VII.

G. GROUND SYSTEM FUNCTIONS

Once the sequence of mission operations within each operational mode has been established, it is possible to identify the functions for the MOC to support such lunar activities. This is considered, in a preliminary fashion, by identifying:

(1) The information which is required by MOC to make command/control decisions and to generate commands.

(2) The information required by the vehicle to cause any desired set of actions.

(3) The processing of information required by MOC (1) to establish the information required by the LRV (2).

The total set of MOC considerations includes functions performed by both equipment and personnel. It is convenient, in analyzing the problem, to separate the equipment functions from the human functions. Information to be accepted and used by humans must first be displayed to them.

The various information-handling functions for each operational sequence, mentioned above, are presented in tabular form in Section VII, in figures entitled "MOC Profile."

H. ANALYSES REMAINING

Analysis of operational profiles and ground system functions remains to be performed for the following conditions:

(1) Nighttime operations (Night Traverse; Night Navigation Update, Night Stationary Science)

(2) Adaptation to Diurnal Change (Sunrise Preparations; Sunset Preparations)

(3) Placement of RGM's

(4) Vehicle condition appraisal or rejuvenation (Major Diagnostic Check-out; Quiescence)

(5) Continuous operations (Mobile Science, Vehicle Analysis; Mission Monitoring)

(6) Mission management (Opportunity Exploitation; Mission Operations Plan Changes)

VI. INTRODUCTION TO OPERATIONAL MODE ANALYSIS

A. SUMMARY OF MODES

The twelve operational modes associated with recurrent activities of the LRV and their sequential interconnections are shown diagrammatically in Fig. 2. This diagram emphasizes the distinction between those modes which recur most frequently, such as the combination "Traverse-Navigation-Science," and those modes which occur only infrequently (e.g., Quiescence, Checkout, RGM's, Seismic). It also emphasizes the distinction between daytime and nighttime operations, as well as between vehicular and infrequent-science operations. The master identification numbers assigned to the individual modes are used throughout the remainder of the report.

B. INDIVIDUAL MODE DESCRIPTIONS

The analysis of individual operational modes is presented, mode by mode, in Section VII. Each mode is prefaced by a statement of its goals and objectives, the scope of its activities, assumptions peculiar to it, and any peculiarities it may present. Nomenclature is defined in Appendix B.

C. OPERATIONS PROFILES

Following the text for each mode is a master diagram, which presents the major sequences which comprise the mode and shows the order in which they are to be executed. The purpose in presenting this diagram and those that follow is not to show the flow of data but to show the logical chronological succession of events. Symbols are defined in Appendix C.

Major sequences are comprised, in turn, of minor sequences. Operations Profile diagrams for the minor sequences follow the diagram for each major sequence. These diagrams are termed "operations profiles," as an extension of the term "mission profile." At the bottom of each block in these diagrams is a numerical identifier which provides a tie to other blocks in the

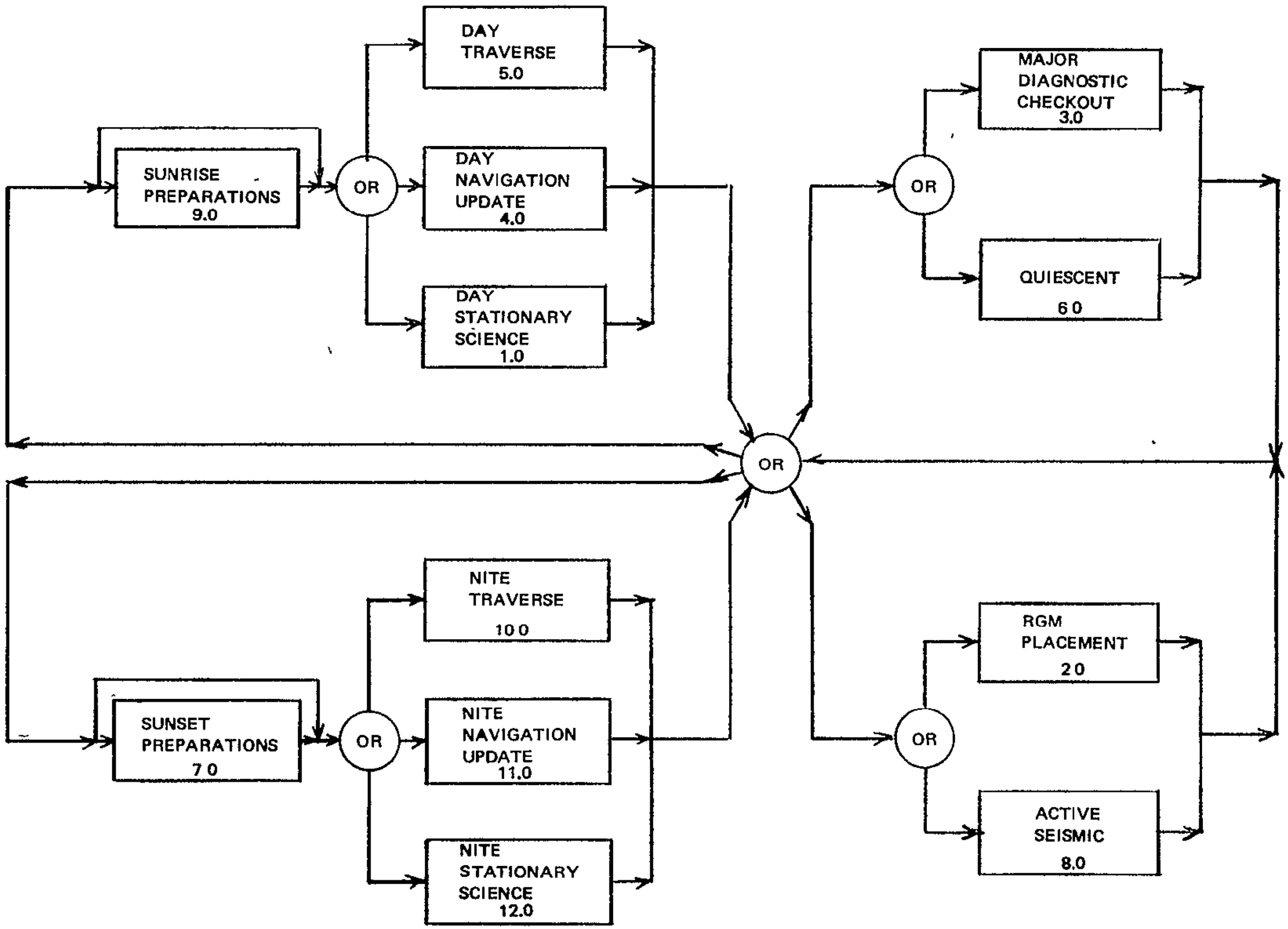

Fig. 2. Roving Vehicle Operating Modes

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diagram, to other operations profile charts, and to the MOC requirements tables described below. The meaning of this decimal number is defined by the following example:

1. 5. 3. 4.

Operational Mode

Major Sequence

Minor Sequence

Detailed Operations

D. GROUND SUPPORT REQUIREMENT TABLES

Immediately following each Operations Profile diagram (except where further diagrammatic breakdown is indicated) is a table describing the ground activities required to support the mission activities shown in the diagram. The intent in presenting these tables is to show the correspondence between each operational activity and all earth-based MOC equipment/activities required for its accomplishment. The operational activity is listed in the extreme left column and numbered as on the operational diagrams. The corresponding MOC characteristics are listed on the same row in the remaining columns of the chart. This columnar arrangement was chosen to illustrate the flow of information and earth-based activities.

The "Information Received" element may be either unprocessed LRV telemetry, earth-generated information (e.g., lunar ephemeris), or information from another segment of the operations organization. The "Information Display" element describes the hardware display or software format of processed information used by people (Human Activities element) to make decisions.

The "Information Processing" element describes the computer program, or other means used to convert part or all of the "Information Received" to the "Information Display." In some applications, a computer program will bypass "Human Activities" to automatically generate and execute a command sequence ("Information Transmitted") for expediency.

The "Information Transmitted" element is counterpart to "Information Received" in that it may be commands transmitted to the LRV or information transmitted to another segment of the operations organization.

VII. ANALYSIS OF INDIVIDUAL MODES

A. DAY STATIONARY SCIENCE MODE (1.0)

1. Objective

The objectives are those science operations which are pertinent to the particular site occupied and can be accomplished only while the vehicle is stationary.

2. Scope.

The scope of this mode includes all stationary science functions.

3. Assumptions

Assumptions required for this mode are shown at the individual sequences affected.

4. Discussion

The Science Mode (1.0) is a reentrant mode; that is, the execution of the mode can be interrupted to execute other modes and then return to the Science Mode at the point of departure.

The general sequence of events for the Science Mode is shown in Fig. 3. This chart portrays the flow of activities in chronological order, without regard to the structural organization of component sequences. Fig. 4 portrays a logical ordering of component sequences within the Science Mode, emphasizing their organizational relationships.

It should be noted that, while the charts show all of the science experiments, any particular execution of the Science Mode may not involve them all but would perform selected experiments in the order shown.

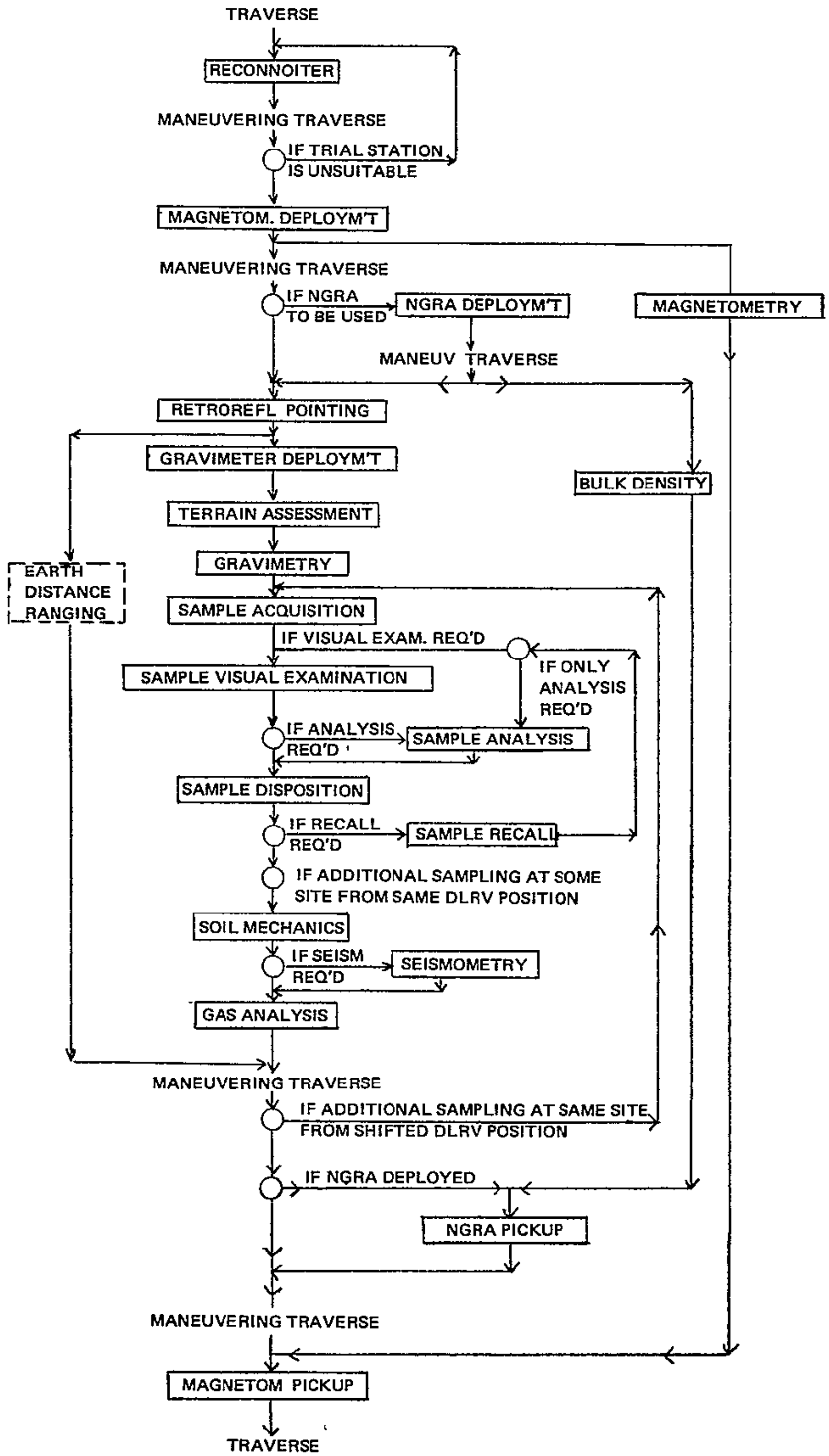

Fig. 3. Chronological Flow of Activities

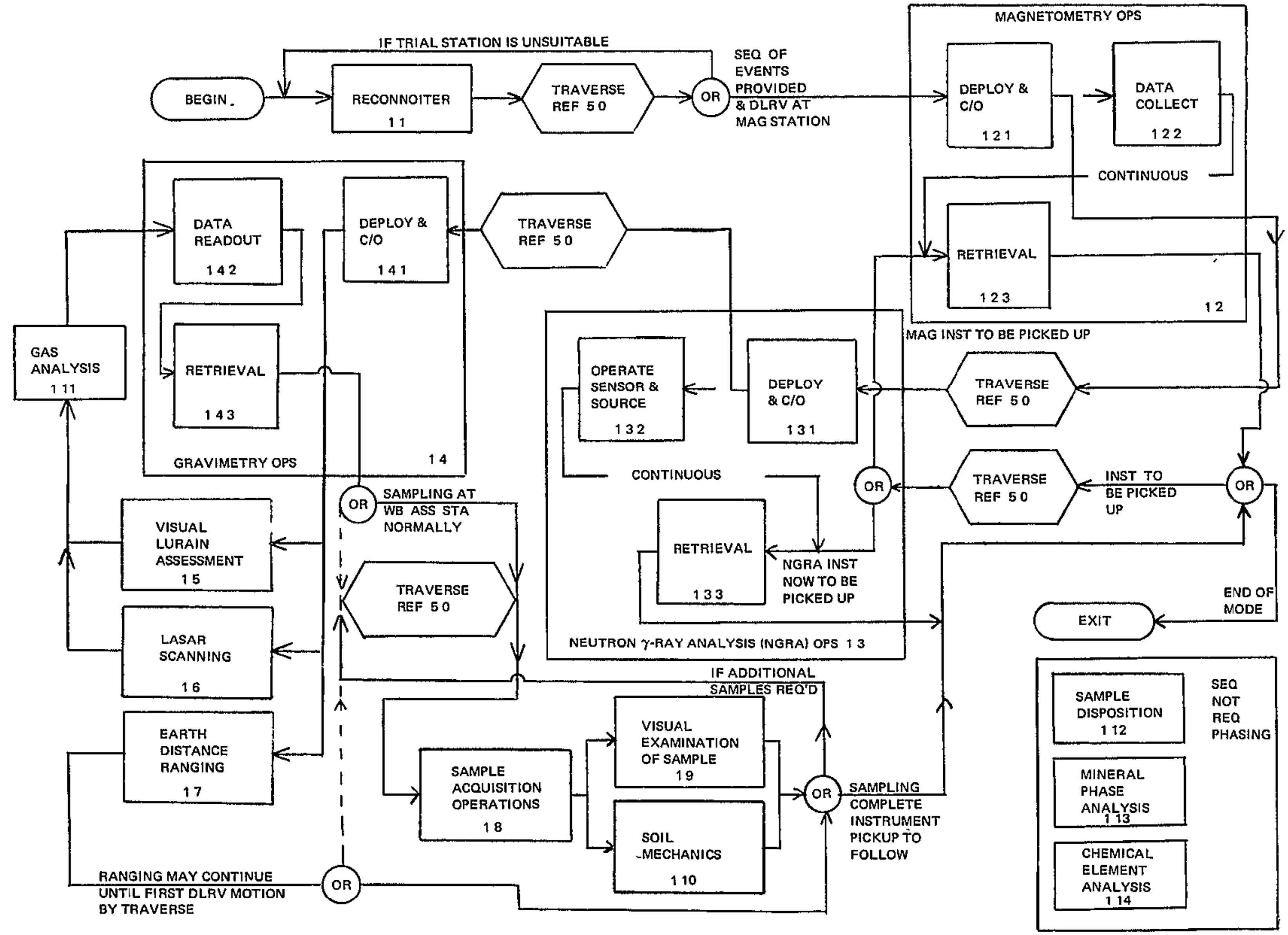

Fig. 4. Mode 1.0 Daytime Stationary Science

B. RECONNAISSANCE MAJOR SEQUENCE (1. 1)

1. Objective

The reconnaissance sequence would enable updating of the plan for science operations at the particular science site to be occupied, amending the Mission Operations Plan on the basis of a direct view of the subject terrain from distances on the order of 20-50 meters.

2. Scope

This major sequence includes:

(1) Quick-look panoramic pictures
(2) Interpretation of panoramic pictures

3. Assumptions.

(1) The Traverse Mode has placed the vehicle in a suitable position (view essentially unobstructed for radial distance of 50 meters) for conduct of this sequence.
(2) Subsequent planned operations require data from the reconnoitering sequence (i. e., data from traverse sequences is not sufficient).
(3) Vehicle position, attitude, and earth and sun line calculations have been accomplished previously.

4. Discussion

This major sequence (Fig. 5) is intended to provide the local information needed to optimize site exploration.

The operations here are similar to those conducted in Terrain Assessment (1. 5) but on a more time-curtailed basis. Demands upon the picture resolution are less stringent. In the event that a particular reconnaissance station does not satisfy mission constraints, the vehicle is shifted to a fresh candidate station and the panoramic pictures repeated.

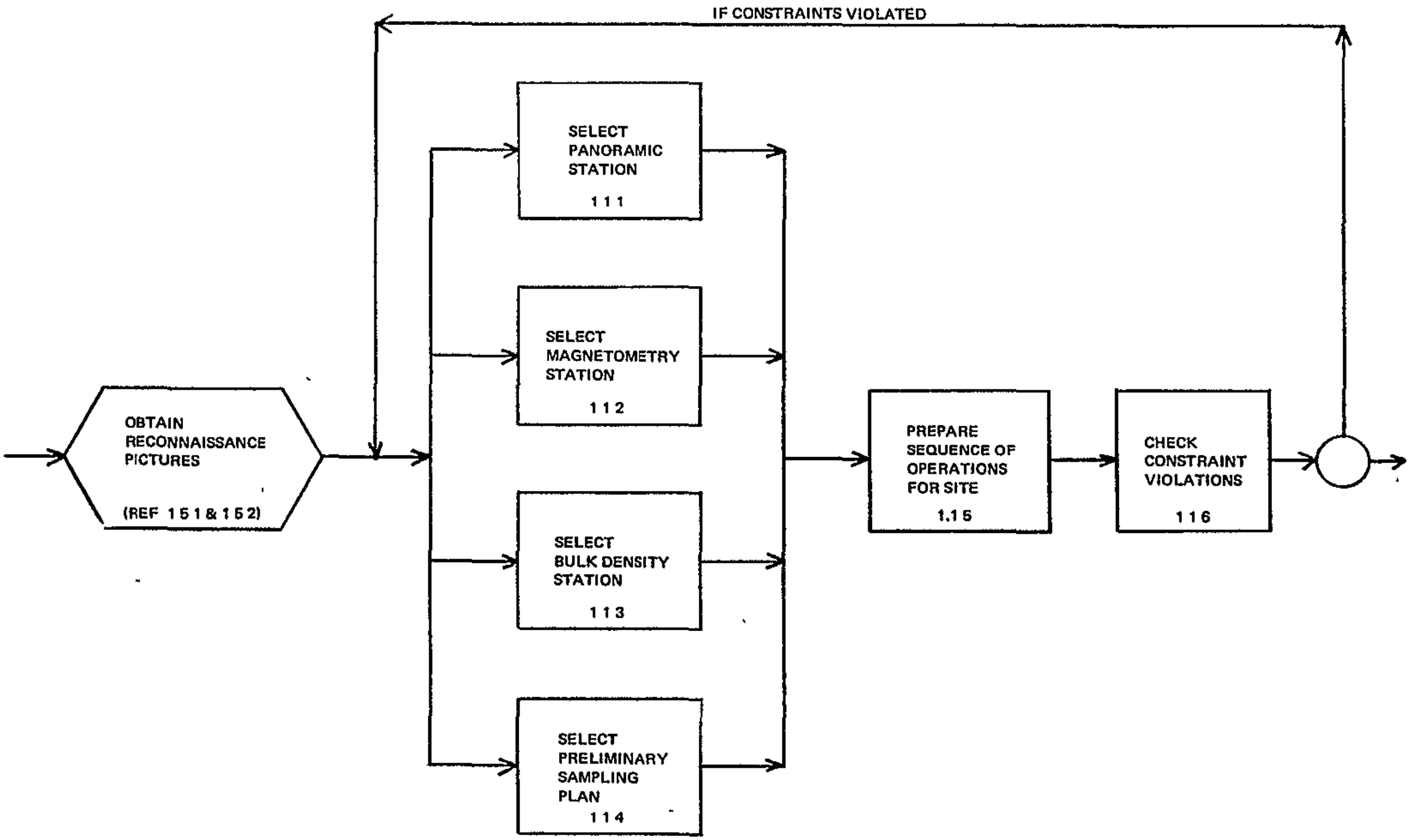

Fig. 5. Sequence 1.1 Reconnoiter

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1 1 RECONNOITER OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 1 1 SELECT PANORAMIC STATION	Review panorama from 1 5 1 etc (preceding) Select station suitable for conduct of 1 4, 1 5, 1 6, 1 7, and 1 11	Panorama	Show selected station on display of panorama and show coordinates of station Identify line of sight (azimuth angle) from reconnaissance station for subsequent display	Panorama and selected station and station coordinates Line of sight to selected station	Analyze panorama for optimum position for conducting sequence 1 4 through 1 7 and 1 11	Coordinates of station given to Navigation/Guidance operations for determination of future LRV repositioning operations	Optimization factors include Height above local terrain Distance from stations of (1 1 7, 1 1 3, and 1 1 4) Vehicle constraints Scientific interest Distance from LRV
1 1 2 SELECT MAGNETOMETRY STATION	Review panorama for selection of LRV station for positioning of magnetometer	Same as above	Same as above	Same as above	Analyze panorama for optimum position for conducting sequence 1 2	Same as above	Optimization factors include Distribution of magnetic disturbances detected during traverse and/or visually Distance from other stations of sequence Security of instrument Vehicle constraints

1 1 RECONNOITER (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1. 1 3 SELECT BULK DENSITY STATION	Review panorama for selection of LRV station for positioning of NGRS	Same as above	Same as above	Same as above	Analyze panorama for optimum position for conducting sequence 1 3	Same as above	Optimization factors include Distribution of possible, visually detected, radio active materials Distance from other stations of sequence Security of instrument Vehicle constraints
1 1. 4 SELECT PRELIMINARY SAMPLING PLAN	Review panorama for selection of LRV station(s) for	Panorama Sampling requests from mineralogy & chemistry	Same as above	Same as above	Analyze panorama for optimum position(s) for conducting sequence 1. 8 and 1. 10	Same as above	Optimization factors include Location of possible mineralogically "interesting" points Distance from other stations of sequence Security of instrument Vehicle constraints

1 1 RECONNOITER (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 1 5 PREPARE SEQUENCE OF OPERATIONS FOR SITE	From data above prepare sequence of operations	Station coordinates for exploration activities Constraints list Activities list Panorama Planned sequence of events (SOE)	Overlay panorama display with stations selected by 1 1 2 2 through 1 1 2 5 Identify stations on panorama with sequence of events (SOE)	Panorama Panorama with stations identified by SOE	From inputed data select optimum sequence of activities from 1) Science requirements for experiments 2) Course plan from navigation/guidance	Sequence of events identified by major and minor sequences	
1 1 6 CHECK CONSTRAINT VIOLATIONS	Check for operational constraints and analyze effect upon science mode	List of current constraints	Computation of power and thermal use by SOE and comparison against allocations	Extrapolated power and thermal curves Delta's against constraints of power and thermal Display of other vehicle constraints and data to be monitored	Check constraints of power, thermal, time, communications, etc Check computer output for constraint violations, if violated, initiate planning iteration	Constraints violated	

C. MAGNETOMETER OPERATIONS

1. Objective

The objective of this sequence is to measure the time-varying intensity and vector direction of the magnetic field at the science site, with minimal electromagnetic interference from the vehicle or from deployed science-instrument packages.

2. Scope

It includes:

(1) Deployment of the magnetometer to a position (magnetically) remote from both the vehicle and all deployed science-instrument packages.

(2) Use of magnetometer data from RGM's and other magnetometers on the lunar surface but not in the vehicle.

(3) Terminal recovery of the magnetometer.

3. Assumptions

(1) Initially, the vehicle is stopped at the magnetometer deployment station.

(2) The magnetometer must be deployed to a location remote from vehicle.

(3) The magnetometer communication lines are provided through LRV.

(4) The magnetometer battery is charged for the duration of operations.

(5) No cabling connections between LRV and magnetometer are required.

4. Discussion.

All activities required for deploying this magnetometer, collecting data, and retrieving the instrument are provided within this sequence, Fig. 6. The deployment and retrieval operations are identical to those employed for NGRA and, in some degree, to those for surface sampling operations.

The deployment operation consists of selecting the spot for deployment by examination of the foreground within reach of the deployment device, computer programmed operations to slew the deployment device (with instrument) to a standoff position short of the deployment spot, and final positioning of the instrument to the selected spot, using video and operator control aids.

Vehicle-generated magnetic fields will be carefully monitored during vehicle withdrawal from and approach to the magnetometer, in order to provide a measure of instrument performance and electro-magnetic interference.

Instrument pickup operation will be similar to deployment, but in reverse order. Retrieval of the magnetometer, Fig. 6, (sequence 1. 2. 3) has not been treated in detail here. The assumption has been made that it is the logical inverse of the deployment sequence (1. 2. 1).

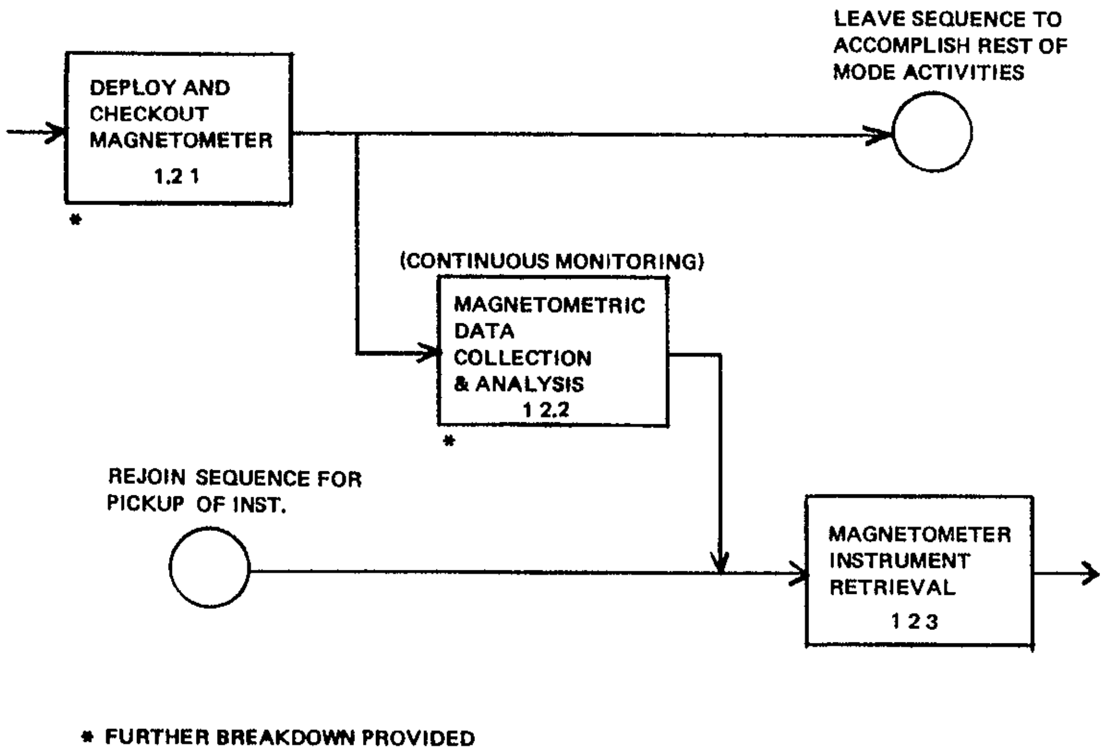

Fig. 6. Major Sequence 1.2 Magnetometry OPS

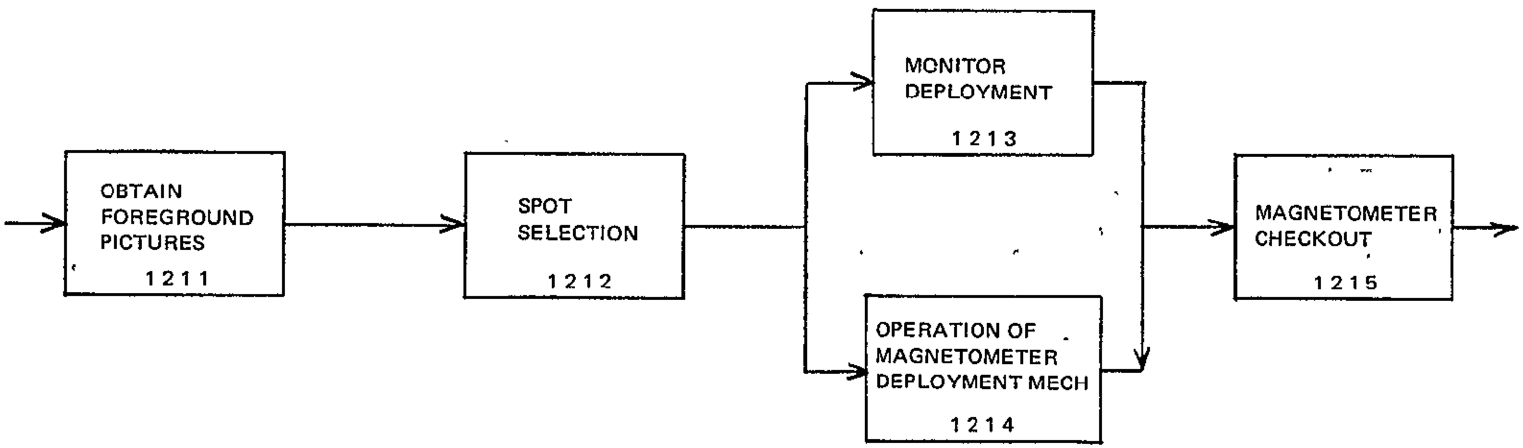

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Fig. 7. Minor Sequence 1.21 Deploy and Checkout Magnetometer

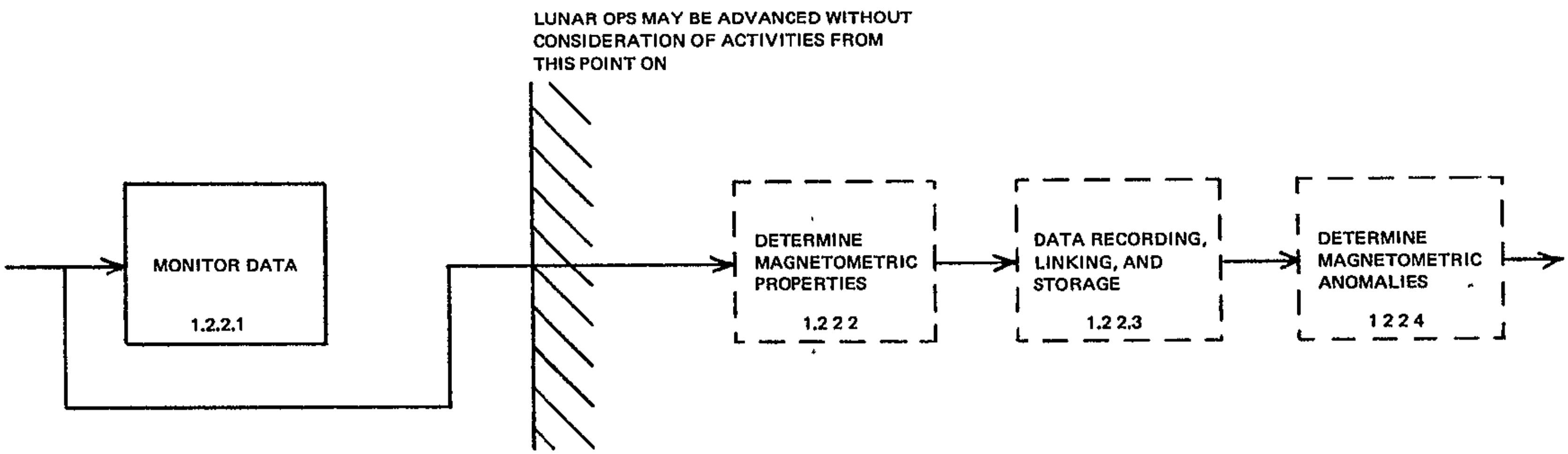

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Fig. 8. Minor Sequence 1. 2. 2 Magnetometric Data Collection

MAGNETOMETRY-OPERATION/ 'DEPLOY AND CHECKOUT MAGNETOMETER	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 2 1.1 OBTAIN FORE-GROUND PICTURES OF DEPLOYMENT LOCATION	Stereo TV pictures of lunar surface within reach of manipulators		(Ref Minor Sequences 1.5 7, 1 5 8, 1 5 9 and 1 5 10)				
1 2 1 2 SPOT SELECTION	Examine fore-ground pictures to determine suitable instru-ment deployment spot	Foreground pictures Targeted line of sight and posi-tion from recon-naissance station	Stereo image of deployment spot on scaled video display Calculation of spot coordinates and manipulator commands from TV look angles and video display Compute line of sight overlay	Display of spot (center of instru-ment) on fore-ground pictures Display of spot on stereo image of foreground Line of sight projection from reconnaissance station	Examine pictures for level, rock-free spot Determine spot coordinates with respect to deploy-ment mech Correlate spot selected with recon selection	Coordinates of spot with respect to deployment mechanism Deployment mechanism posi-tioning commands	Scaled video display Provide azimuth and range scales overlaid on video presentation
1 2 1 3 MONITOR DEPLOYMENT	Monitoring of deployment oper-ation by terrain assessment camera	Deployment spot location and required manipulator position Automatic rou-tine to steer camera for pic-ture sequences of mechanism movement	Compute video steering com-mands to follow mechanism movement Compute effect of mechanism deployment commands and display as trace overlay on video display	Video display of mechanism at all times Required angular and extension changes to reach deployment spot Predicted effect of deployment mechanism repositioning commands as shown on video display	Monitoring proper execution of sequence	Uplink camera command to follow mechan-ism movement, etc	

MAGNETOMETRY-OPERATION/ DEPLOY AND CHECKOUT MAGNETOMETER (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1. 2. 1 4 OPERATION OF MAGNETOMETER DEPLOYMENT MECHANISM	Commanding deployment mechanism to settle NGRA on preselected spot	Terrain assessment camera stereo video and data Deployment mechanism data	Display of stereo data on scaled video display device Display of projected deployment mechanism position as result of commands to be sent Command sequence prepared for operational control of manipulator	Stereo pictures of deployment operation Predicted effect of deployment mechanism repositioning commands as shown on video display Deployment device data Target overlay	Analysis of video display for proper deployment operation Preparation of uplink commands Manipulate operator control device to control mechanism movement	Uplink terrain assessment camera and deployment device commands	
1. 2. 1. 5 MAGNETOMETER CHECKOUT	Pulsing of helmholtz type of coils to calibrate instrument Monitoring of LRV departure/approach	Magnetometer output	Develop display curves from magnetometer data	Curves of magnetometer calibration and vehicle departure approach (Field intensity is distance of vehicle)	Monitor data for proper instrument operation Observe vehicle field for corresponding with calculated or previous data	Uplink magnetometer pulsing commands	Vehicle motion is commanded during this sequence Field changes from resulting motion are monitored

MAGNETOMETRY OPERATIONS (contd)/MAGNETOMETRIC DATA COLLECTION AND ANALYSIS OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 2 2 1 DATA SENSING AND TRANSMISSION	Sense data and transmit to earth Store data on earth	Magnetometric data	Format data for storage Compute magnetic field vector	Real time display of raw magnetometric data Display of preliminary computed vector	Monitor data for proper operation of instrument	None	RGM data (if device deployed) will also be received to determine natural magnetic background
1 2 2 2 DETERMINE MAGNETOMETRIC PROPERTIES	Retrieve magnetic data Deduct artificial and temporal magnetic background data Tab results	Magnetometric data RGM data LRV magnetic field calculations	Process magnetic data and deduct temporal and artificial background Compute final vector	Tabulation of magnetic properties data as functions of time A Natural background B Vehicle induced electromagnetic interference C Net spatial	None	None	
1 2 2 3 DATA RECORDING, LINKING, AND STORAGE	Recording of magnetometric data vs selenographic position, time, features, etc	Selenographic position Magnetic data Selenographic characteristics, etc	Store tagged data	Tabulation of tagged data	None	None	Data identification implies an attempt to relate all data to date from aspect of time, lunar position, close geologic feature, lunar region, etc
1 2 2 4 DETERMINE MAGNETOMETRIC ANOMALIES	Analysis of current data in light of previous and RGM data to detect spatial and temporal magnetic anomalies	Net spatial magnetometric data	Update statistical model Determine deviation of new data from model Store information on anomalies	Tabulation of spatial and temporal anomalies Plot as desired	Examination of current magnetometric data and correlation with previous data		Anomalies will be defined as significant deviations of current data from norm of previous data

D. NGRA OPERATIONS SEQUENCE (1. 3)

1. Objective

The objective of this sequence is to meet all requirements involving use of the NGRA which arise out of:

(1) The Bulk Density Experiment

(2) The Chemical Composition Experiment

2. Scope

It involves deployment of the NGRA at distances remote from both the magnetometer and the LRV. It involves use of the NGRA in its several operational modes and the terminal recovery of instrument.

3. Assumptions

(1) Initially, the vehicle is stopped at the NGRA deployment station.

(2) The NGRA must be deployed to a remote location from vehicle.

(3) The NGRA communication links are provided through LRV, with no cabling required.

(4) The NGRA battery is charged sufficiently for the duration of operations.

4. Discussion

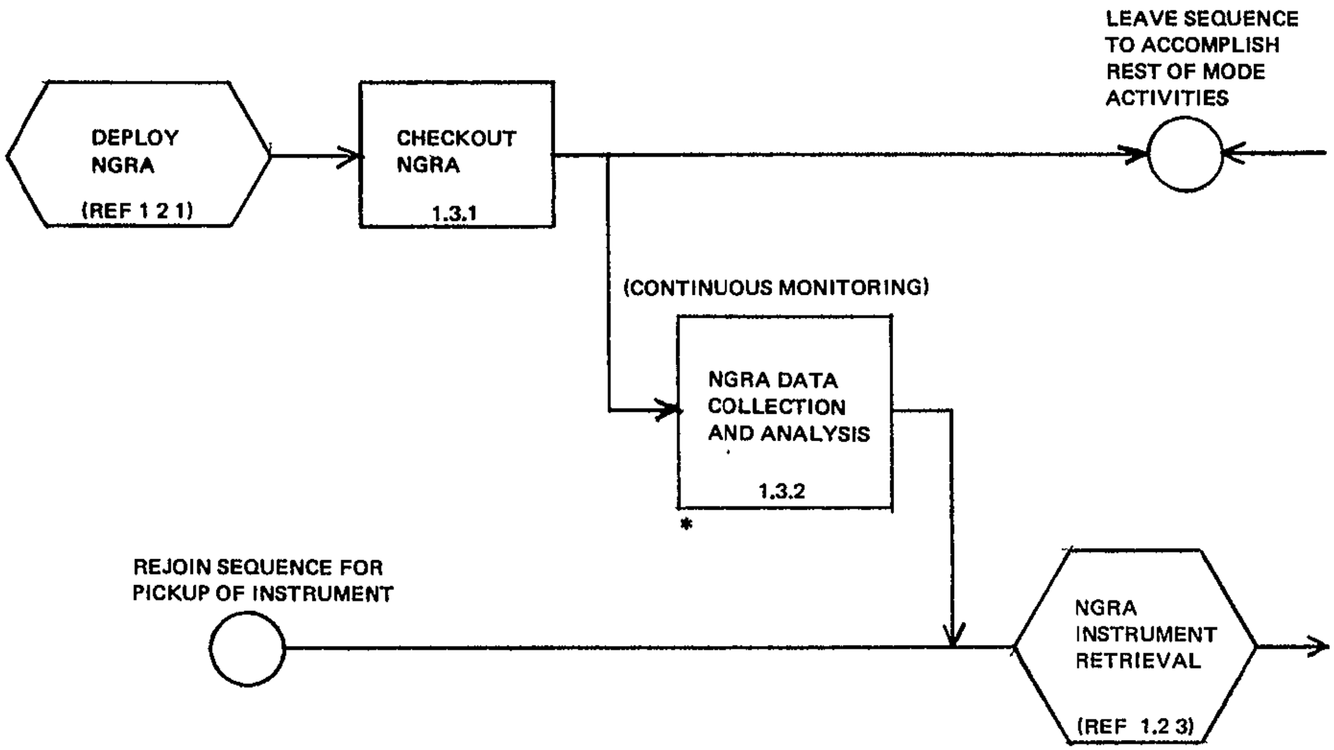
All activities required for deploying the NGRA, operating and collecting data, and retrieving the device are provided within this major sequence (Fig. 9). The deployment and retrieval operations are basically identical to those discussed under Magnetometry (Fig. 6).

Operation of the instrument and collection of data will consist of sensor activities for monitoring of background radioactive events. This will be followed by operation of the neutron source in its various modes while monitoring

stimulated radioactive events. Data will be collected and assembled into a spectrogram of event counts for each channel of the energy spectrum. This assembly will be accomplished in real-time with non-real-time analysis consisting primarily of curve fitting, accumulated data with a library of standard curves to determine the chemical element and bulk density information. Reasons for remote placement are:

(1) The possible influence of NGRA radiation on the magnetometer.

(2) The possible influence of vehicle RTG radiation on the NGRA.



* FURTHER BREAKDOWN PROVIDED

Fig. 9. Major Sequence 1.3 NGRA Operations

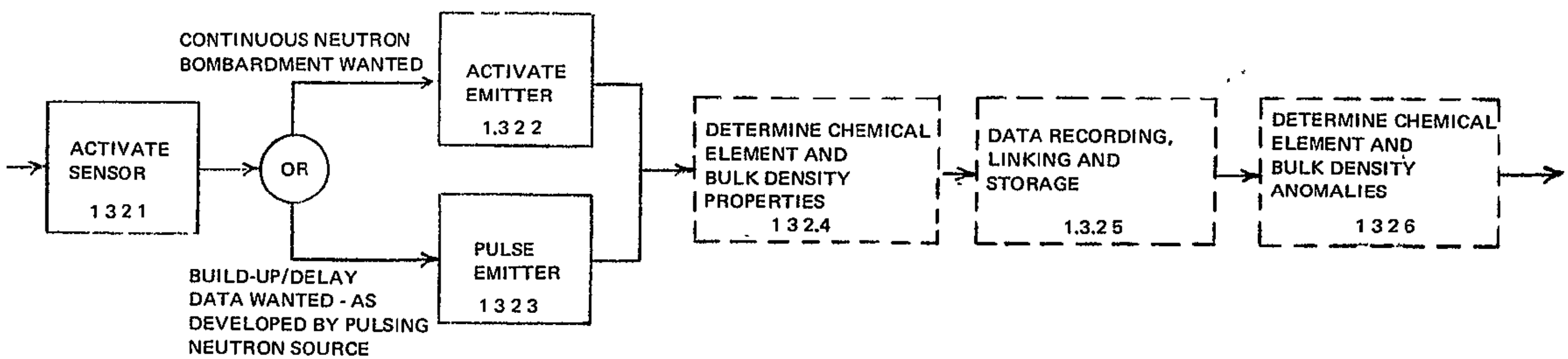


Fig. 10. Minor Sequence 1. 3. 2 NGRA Data Collection and Analysis

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NGRA OPERATIONS	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.3.1 NGRA CHECKOUT	Check for proper operation of up/down links	Up/down link command/data • Commands transmitted • NGRA response	• Computer program to provide tally of detector sensed events • Computer program to check conformity of data	• Display of detector/emitter data • Tabulation of accomulated data	• Analysis of instrument data for proper operation	• Uplink commands for control of instrument for test purposes	Assume NGRA inst has remote pwr, uplink, and downlink capability (RF links may be thru LRV)
1.3.2.1 ACTIVATE SENSOR	• Activate sensor and monitor data to assure activation • Accumulate NGRA data	• Sensor data • Currents • Temps • Event counts	• Computer prog to provide tally of sensor detected events • Processing of sensor data for display	• Sensor data • Tabulation of accumulated sensor detected events	• Monitor data to assure activation of sensor and cont proper operation of instrument	• Sensor turn on command	
1.3 2 2 ACTIVATE EMITTER	• Activate emitter and accumulate NGRA data	• Sensor data • Emitter data	• Same as 1 3.2 1 • Processing of emitter data for display	• Same as 1 3 2 1 • Emitter data	• Monitor data to assure activation of sensor and cont proper operation of instrument	• Emitter turn on command	
1 3 2 3 PULSE EMITTER	• Provide emitter pulsing and accumulate data	• Sensor data • Emitter data	• Same as 1.4.5 • Computer prog (?) to provide event build-up and delay curves (intensity vs energy vs time)	• Same as 1.4.5 • Build-up and delay curves of monitored events	• Same as 1 4 5	• Emitter pulsing command	

NGRA OPERATIONS (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 3 2 4 DETERMINE CHEMICAL ELEMENT AND BULK DENSITY PROPERTIES	• Analysis of accumulated data, preparation of statistical curves, and pattern matching of data to baselines	• Instrument event tabulations	• Computer program to provide statistical curves of event data (intensity vs energy) • Computer program to provide matching of statistical data with mineral comp baselines	• Curves of event data • Water content • Mineral comp and abundance	• Analyze curves for bulk density info	• None	
1 3 2 5 DATA RECORDING, LINKING, AND STORAGE	• Recording of bulk density data vs selenographic position, time, features, etc.	• Curves of event data and correlated bulk density info	• Computer storage of profile data	• Tabulation of profile data	• Correlate selenographic position with bulk density data	• None	(See note 1 2 2 3)
1 3 2 6 DETERMINE CHEMICAL ELEMENT AND BULK DENSITY ANOMALIES	• Analysis of current data in light of previous data to detect deviation of new data from model	• Bulk density data	• Update statistical model • Determine deviation of new data from model • Store info on anomalies	• Tabulation of anomalies	• Examination of current bulk density data and correlation with previous data	• None	Anomalies will be defined as significant deviations of current data from norm of previous data

E. GRAVIMETRY OPERATIONS SEQUENCE (1.4)

1. Objective

The objective of this sequence is to meet all operational requirements of the Gravimetry Experiment, Ref. 2, except those related to the selection of observation stations.

2. Scope

It utilizes data from lunar measurements of the acceleration of gravity, laser topography, and earth tracking to determine gravitational anomalies.

3. Assumptions

(1) The Traverse Mode has confirmed the suitability of the "spot" to which the gravimeter will be lowered. This has been done by foreground survey and spot selection sequences (similar to 1.2.1.1 and 1.2.1.2, see Fig. 7) within the traverse mode. These sequences have been accomplished prior to the vehicle's reaching the gravimetry station.

(2) Lunar radial distances from the lunar mass centroid to the LRV have been or are capable of being calculated for the gravimetry station selected.

4. Discussion

The gravimeter operation (Fig. 11) will normally be conducted at the station designated for Visual Terrain Assessment (Fig. 14), and Laser Scanning (Fig. 15). The prime constraint for conducting the gravimetry sequence during this interval is that the gravimeter requires significant damping time, once activated, in order to obtain a satisfactory reading. Activities at the Visual Assessment station will be quiescent and will require approximately a half hour, so it appears that the gravimetry experiment can be accommodated without adding time to the sequence of events.

Gravimetry activities include lowering the device to the lunar surface through a hole in the center of the LRV. The vehicle center has been chosen

to provide symmetric vehicle mass distribution around the instrument. Lowering and subsequent leveling operations will be monitored with the television system.

Once the gravimeter is lowered and activated, other vehicle-quiescent activities can be initiated until the device has damped sufficiently for a stable reading. Subsequent to reading, the instrument will be raised and stowed.

Observation stations for gravimetry will have been selected in terrain assessment operations or earlier.

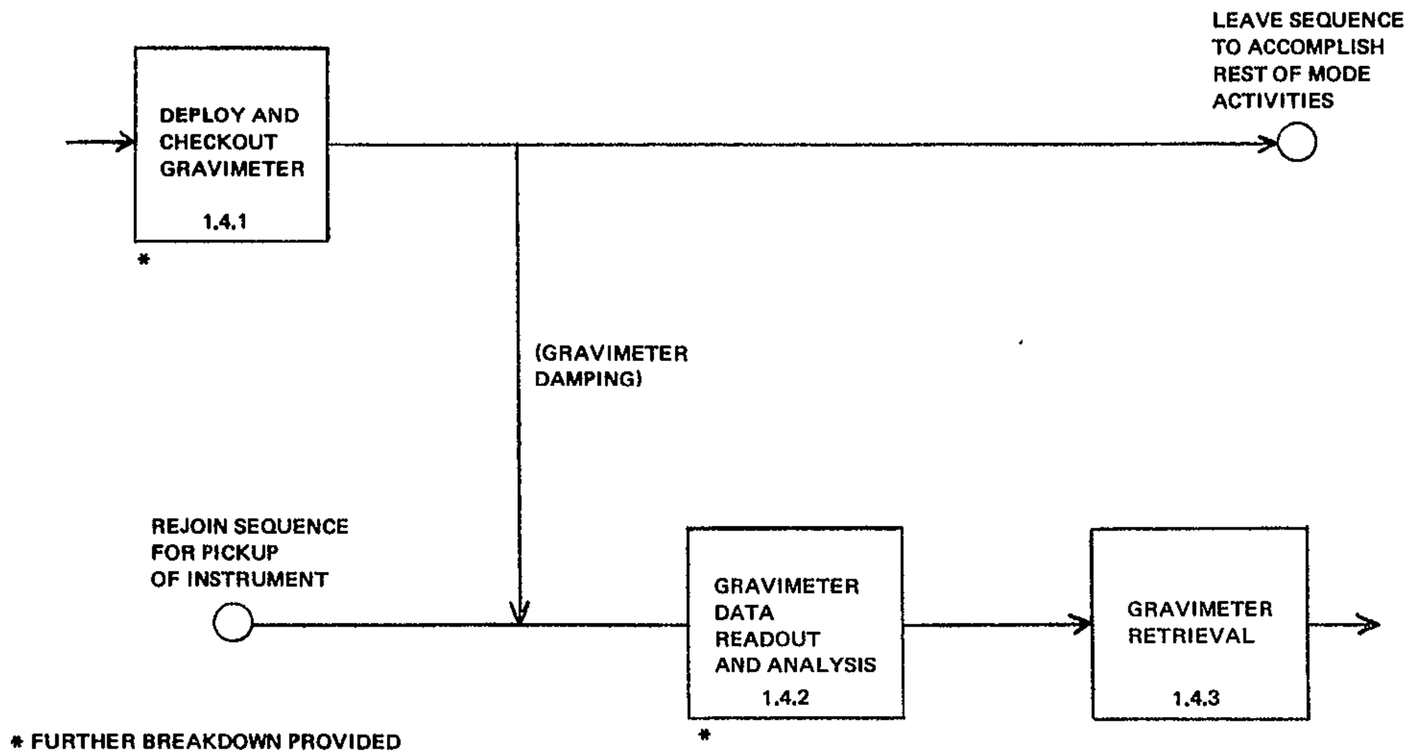

Fig. 11. Major Sequence 1.4 Gravimeter Operations

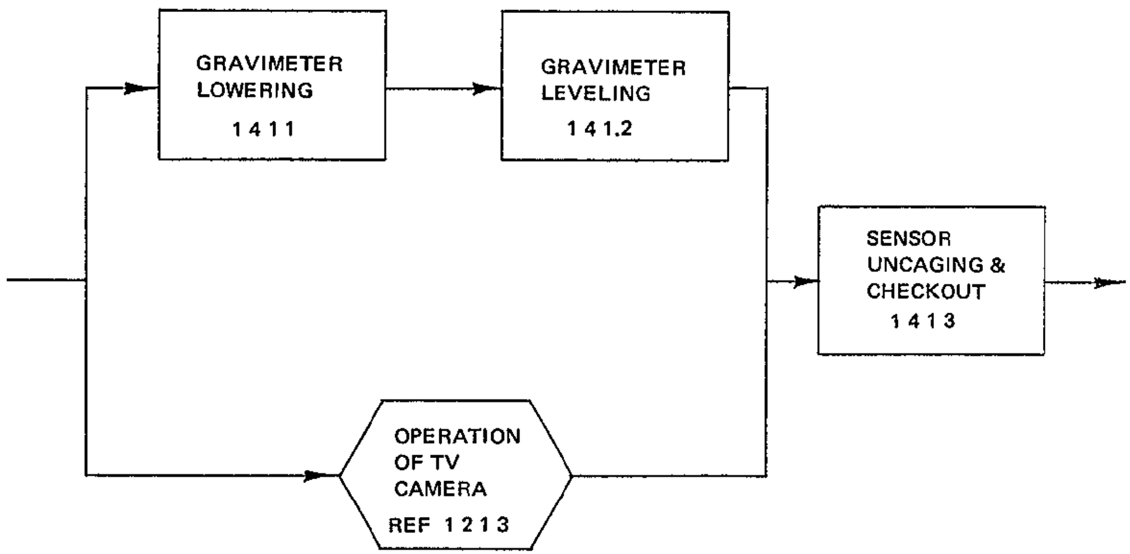

Fig. 12. Minor Sequence 1.4.1 Gravimeter Deployment and C/O

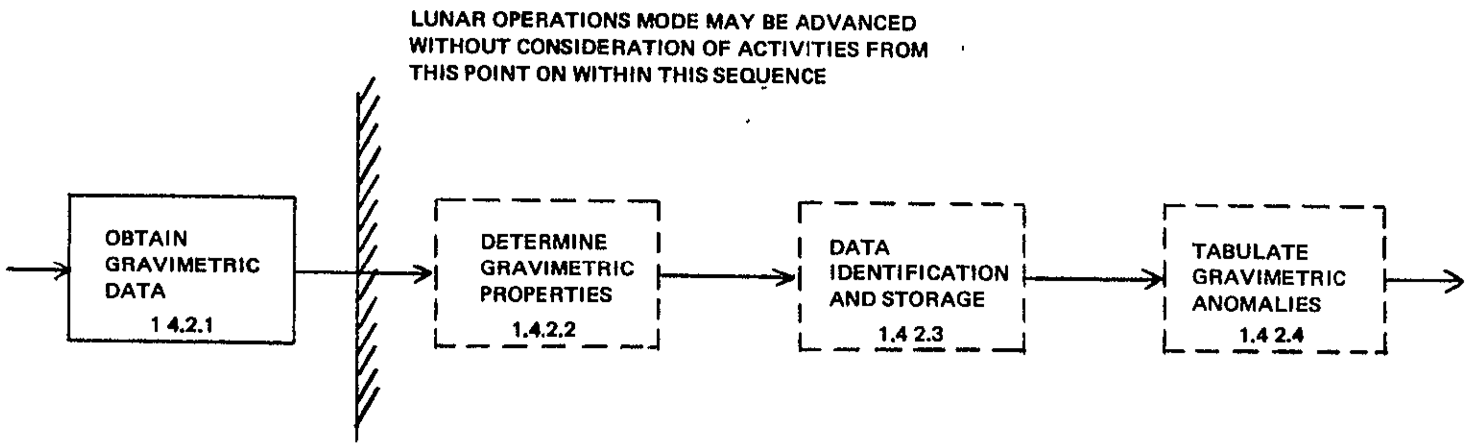

Fig. 13. Minor Sequence 1.4.2 Gravimetry Data Readout and Analysis

GRAVIMETRY OPERATIONS	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 4 1 1 GRAVIMETER LOWERING	Lower gravimeter through vehicle to lunar surface	Gravimetric data Lowering device data Terrain assessment camera data Lowering termination measurement (i e force or distance)	Terrain assessment and TV data for display Lowering termination limit detection	TV monitoring of lowering operations Data readout of lowering termination measurement	Monitor lowering operations with video Execute lowering commands	Uplink lowering commands	Assumes lowering device to be screw or string arrangement always connected to gravimeter
1 4 1 2 GRAVIMETER LEVELING	Level gravimeter as deployed on surface	Gravimetric data Lowering device data Terrain assessment camera data	Computation of required leveling correlation from data readout or video presentation	TV monitoring of leveling operations Leveling correction required	Monitoring of leveling operations Execute leveling commands	Uplink leveling commands	
1 4 1 3 SENSOR UNCAGING AND CHECKOUT	Uncaging of sensor monitoring of gravimetric data	Gravimeter readout	None	Trace of gravimeter transient at uncaging	Monitor decay of gravimeter transient at uncaging to determine proper operation	Uplink commands	
1 4 1 4 OPERATION OF TV CAMERA				(Ref sequence 1 2 1 3)			
1 4 2 1 OBTAIN GRAVIMETRIC DATA	Obtain readings and average data	Gravimetric data	Store and average data	Accumulated readings and computed average	Execute reading process and monitor data	Uplink reading commands	Assumes gravimeter reading taken on command
1 4 2 2 DETERMINE GRAVIMETER PROPERTIES	Retrieve gravimetry data Determine elevation topographic and soil density corrections Tabulate results	Gravimetry data Visual analysis data Elevation data from laser tracking station	Calculation of correction data	Tabulation of gravimetric properties	Analyze tabulation for gravimetric information	None	

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2

GRAVIMETRY OPERATIONS (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 4 2 3 *DATA IDENTIFICATION* AND STORAGE	*Recording of gravimetric data vs selenographic position, time, features, etc*	*Selenographic* position Gravimetric data *Selenographic* characteristics, etc	*Store tagged data*	Tabulation *of* tagged data	*Identify* data tagging factors	Data tagging factors	(See Note 1 2 2 3)
1.4 2.4 TABULATE GRAVIMETRIC ANOMALIES	Analysis of current data in light of previous and RGM data	Gravimetric data	Update statistical model Determine deviation of new data *from model* Store information on anomalies	Tabulation of anomalies	Examination of current gravimetric data & correlation with previous data		(See comments 1 2 2 4)
1 4 3 Gravimeter Retrieval	Cage and retriev gravimeter	• Gravimetric data • Terrain assessment camera video and data • Retrieval device data	• Video data for display • Gravimeter and retrieval device data for display	• TV pictures of retrieval operations • Gravimeter and device data	• Analysis of video display for proper retrieval and stowage operations • Preparation of uplink commands	• Uplink gravimetry • Terrain assessment camera, and retrieval device commands	• Assumes retrieval to be caging and hoisting of gravimeter (Ref 1 4 1 1)

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F. VISUAL TERRAIN ASSESSMENT SEQUENCE (1.5)

1. Objective

The objective of this sequence is to meet all requirements of the Terrain Assessment Experiment (Ref. 2) except those related to Laser Scanning. They are 1) the performance of geological reconnaissance and 2) the amendment of the Lunar Operations Plan to exploit encountered opportunities for science.

2. Scope

It includes taking panoramic pictures at intermediate resolution and pictures of selected portions of the terrain at high resolution. Also included is the amendment of the Lunar Operations Plan, with consideration of all mission objectives and mission constraints.

3. Assumption

The vehicle is stopped at a location which provides suitable visibility of the surrounding terrain.

4. Discussion

This sequence (Fig. 14) provides all activities required for operation of the Facsimile (Fax) Camera for panoramic picture sequences and operation of the Terrain Assessment (TA) camera for detailed lunar feature imaging.

The Fax camera permits rapid acquisition of 360 degree field of view pictures over wide depth of field. The TA camera permits the taking of high resolution pictures at commandable look angles which will be selected from examination of the panoramic display.

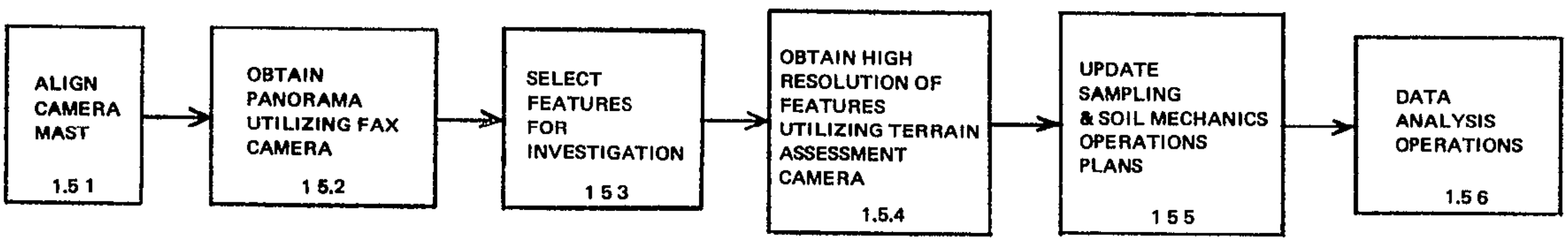

Fig. 14. Major Sequence 1.5 Visual Terrain Assessment

1 5 TERRAIN ASSESSMENT	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.5.1 INITIALIZE CAMERA SETTING	Select Camera Align mast Point camera Uncover lens Check thermal conditions	Vehicle heading, pitch and roll Mast tilt angle Camera pointing angle Lens cover position Camera temperature	Control mast alignment Control camera alignment Calculate sun angle	Magnitude of vehicle heading, vehicle pitch, vehicle roll, mast tilt angle, camera pointing angle, lens cover position, camera temperature, sun angle Camera identification	Select camera Command mast alignment Designate pointing angle Command lens uncovering Check thermal conditions Avoid glare	Camera selection Mast alignment command Camera pointing angle Lens uncovering command Thermal control resettings	Camera may be facsimile or TV No stereo Dust and glare to be avoided TV sensitive to temperature
1.5 2 ADJUST PHOTO PARAMETERS	Select Lens focal length Lens focus Iris aperture Shutter exposure Filter used Photoelectric sensitivity	Lens in use or zoom focal length Lens-focusing position Sun angle (1.5 1) and stop Exposure time Filter Sensitivity setting Prior TV data	Calculate optimum exposure, optimum sensitivity	Magnitude of sun angle, lens focal length, lens coordinate and stop, shutter speed, filter in use, photosensitivity Prior TV pictures of region	Select lens or command zoom focal length Command focus Command iris Command shutter Select filter Command sensitivity Review glare and prior light level	Lens selection Focal length command Focus command Iris command Shutter command Filter selection Sensitivity command	Lenses may be interchanged or zoomed Human commands needed only if over-ride of automatic system required
1 5 3 EXPOSE, PROCESS AND DISPLAY	Exposure and Transmit Apply photo calibration Eliminate automatic correctable errors Display picture Overlay reference grid	TV telemetry data Vehicle heading Camera pointing angle	Generate TV display Detect and eliminate correctable errors Compute overlay reference grid	TV picture plus reference grid overlay Errors corrected Camera status Vehicle heading	Command exposure Select type of reference grid	Picture-taking command Grid-type command	Fully automatized sequence Reference grid may be polar or rectangular

1 1 5 TERRAIN ASSESSMENT (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 5 4 ASSESS IMAGE QUALITY	Detect any identifiable elements of unsatisfactory imaging Establish causes	TV display data from 1 5 3 output	Simulate effect upon image to be achieved by change in TV controls	TV display data from 1. 5 3 output Changes in image to be expected with candidate changes in control Identity of errors	Detect any unsatisfactory conditions in photo image Identify cause Command simulation Establish confirmation of cause	Command simulation of suspected errors Command corrective action for confirmed actual causes	Simulation is solely around activity Corrections go to LRV vehicle
1 5. 5 INTERPRET GEOLOGIC CONTENT	Identify principal geologic features Identify anomalies Establish direction and range to features Estimate significance of features Identify primary operations needed to exploit	TV display data from 1 5. 3 output	Track light pen Compute feature coordinates Store feature coordinates and associated function-box annotations Generate annotation display	TV display data from 1 5 3 output Light-pen blinker Annotations Boundaries of potential investigation areas	Point light pen to geologic features Using function box identify type, scientific value, and estimated range Identify anomalies Using light pen, show bounds of feature and possible approach	None	Point out both apex and bounds of interest for each feature Include potential sampling sites Trace contacts Identify best means of investigation
1 5 1 ALIGN CAMERA MAST	From known LRV attitude data and/ or mast readouts align camera axis parallel to local vertical and horizontal	LRV attitude Mast readouts	Computation of required mast changes and associated commands DAC and transformation to engineering units of mast data	Mast readouts	Compare actual mast with required position and monitor proper execution of command sequence	Uplink command to align mast	
1 5 2 1 INITIALIZE PANORAMIC (FAX) CAMERA	Preset camera to start point Uncover lens heaters, etc	FAX camera engineering data Vehicle azimuthal heading	Convert data stream into TV data display	FAX pointing and engineering data to monitor camera conditions	Analyze TV camera for proper initial conditions	Uplink camera initialization commands	Assume all panoramas to start at lunar north heading

OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 5 2 2 ADJUST PANORAMA CONTROLS	Sensitivity, iris, focus, etc commanding to obtain optimum photo quality	Illumination level from 1 1/1 5 4 Focal distances Corrective commands if any, from 1 5 4	Same as above	TV camera data	Analyze data for proper settings	Uplink camera adjustments commands	
1 5 2 3 OBTAIN PANORAMA	Sensing and display of panorama data	TV video Range data from 1 6	Convert retrieved video into panorama display Log and record panorama data for subsequent access Provide video hardcopy Compute azimuth and Range overlay for update of display	A panoramic hemispheric display Video hardcopy Superimpose an overlay of azimuth and range	Initiate picture commands Monitor conduct of video sequence	Uplink picture commands	Sun glare avoidance is not a problem for FAX
1 5 2 4 ANALYZE PANORAMA QUALITY	Review panorama display if unsuitable, determine adjustments required	Panorama display Picture quality requirements	None	None	Check panorama picture quality, against requirements and determine corrective commands as required	Uplink command prepared as required Range of local illumination	
1 5 2 5 SHUT DOWN PANORAMA CAMERA	Transmit commands to shut down and protect panorama camera	Panorama (FAX) camera data (TM)	Convert data into display	Camera data	Analyze TV camera data for proper shutdown conditions	Uplink camera shutdown commands	

OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 5 3 SELECT FEATURES FOR DETAILED OPTICAL INVESTIGATION	Select from the panorama geologic features for terrain assessment camera and/or laser scan investigation Provide pointing data Provide assessment requirements	Panorama display Requirements for *feature investigation* from lunar operations plan or navigation operations Laser range and vehicle status	Perform feature selection computation program (see text) Compute coordinate location of feature	Scientific value of coordinate feature *Resource investment* cost per feature Ratio of value to cost for each type of feature Resource availability Recommended investigation plan	Identify feature Establish coordi*nate input* Estimate science value Propose extent of investigation Review computer recommendation Determine exposure key required	Pointing data for both laser and terrain assessment camera Assessment requirements	Catalog of standard values provided for lunar feature types History of explored features to date
1.5 4 1 POINT TERRAIN ASSESSMENT CAMERA AT COVERAGE AREA	Preset camera to desired pointing to obtain photo coverage of feature	Desired pointing data from 1. 5 6 Preset terrain assessment cam*era pointing* TM data Vehicle attitude	Compute required pointing angle and associated commands	Camera pointing data	Confirm proper initial conditions	Uplink pointing commands	
1 5 4 2 ADJUST CAMERA CONTROLS	Commanding of iris, shutter, focus, etc to obtain optimum photo quality	Illumination Sun position Focal distances Corrective commands, if any, from 1 5 10 Exposure key requirements (from 1 5 6)	Compute sun glare avoidance requirements	TV camera engineering data	Same as above	Uplink camera adjustment commands	Illumination level from panoramic operations Focal distance from laser or terrain model

OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 5 4 3 OBTAIN TV PICTURE	Display of terrain assessment camera video	TV video	Convert TV video into display (stereo capability to be considered) Log and record video for subsequent access Provided video hardcopy Compute range/azimuth overlay	Video display Video hardcopy Range/azimuth overlay	Initialize commands for picture taking Monitor sequence	Uplink picture commands	
1 5 4 4 ANALYZE PICTURE	Review picture, if unsuitable, determine adjustment commands required	Video display Picture quality requirements	None	None	Check picture quality against requirements and determine corrective commands as required Update exposure key	Uplink command prepared as required	
1 5 4 5 SHUT DOWN TERRAIN ASSESSMENT CAMERA	Transmit commands to shutdown and protect terrain assessment camera	Terrain assessment camera engineering data	Convert TM data into display information	Camera engineering data	Analyze TV camera data for proper shutdown condition	Uplink shutdown commands	
1 5 5 UPDATE SAMPLING AND SOIL MECHANICS OPERATIONS PLANS	Review video data including panorama to determine if adjustment necessary to sampling plan (better sample available)	All video data taken at station Range data to stations Vehicle status Requirements for sampling and soil mechanics	Perform selection computation to update sampling and soil mechanics plans	Sampling site selection overlaid on panorama display (Ref 1 5 6)	(Ref 1 5 6)	Coordinates and line of sight of new sampling stations to Navigation/Guidance as required	

OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.5 6 1 DETERMINE VISUAL CHARACTERISTICS OF AREA	Modeling of accumulated data	Same as above	Logging and recording of tabulation	Tabulation of visual characteristics	Analyze video data for geologic characteristics and provide model	None	
1 5 6 2 DATA RECORDING, LINKING AND STORAGE	Recording of visual characteristics vs selenographic position, time, features, etc	Tabulations of 1 5 13	Storage of tagged data	Tabulation of tagged data	Correlate selenographic time, features, etc position with visual characteristics of area	None	(See note 1 2 2 3)
1 5 6 3 DETERMINE VISUAL ANOMALIES	Analysis of current data in light of previous data	• Visual char data	• Update statistical model • Determination of deviation of new data from model • Store info on anomalies	Tabulation of anomalies	Examination of current visual analysis data and correlation with previous data	None	Anomalies will be defined as significant deviations of current data from norm of previous data

G. LASER SCANNING MAJOR SEQUENCE (1.6)

1. Objective

The objective of this sequence is to provide topographic mapping of the visible surface about the station occupied, map-matching capability for high resolution position fixing, and albedo measurements of surrounding surface.

2. Scope

It includes automatic preparation of topographic and albedo maps and the matching of observed terrain features with reference maps.

3. Assumptions.

Laser and TV operations are non-conflicting.

4. Discussion

The laser scanning operation (Fig. 15) will consist of near-field laser range and albedo measurements. Operation of the device will consist of pointing the scan head in the proper direction, initializing the device, and initiating the scan over the desired coverage area. The sweep is then conducted automatically, with real time CRT displays provided for qualitative analysis of the received data so that adjustments and rescans may be accomplished as required. Topographic and albedo maps will be prepared in non-real time.

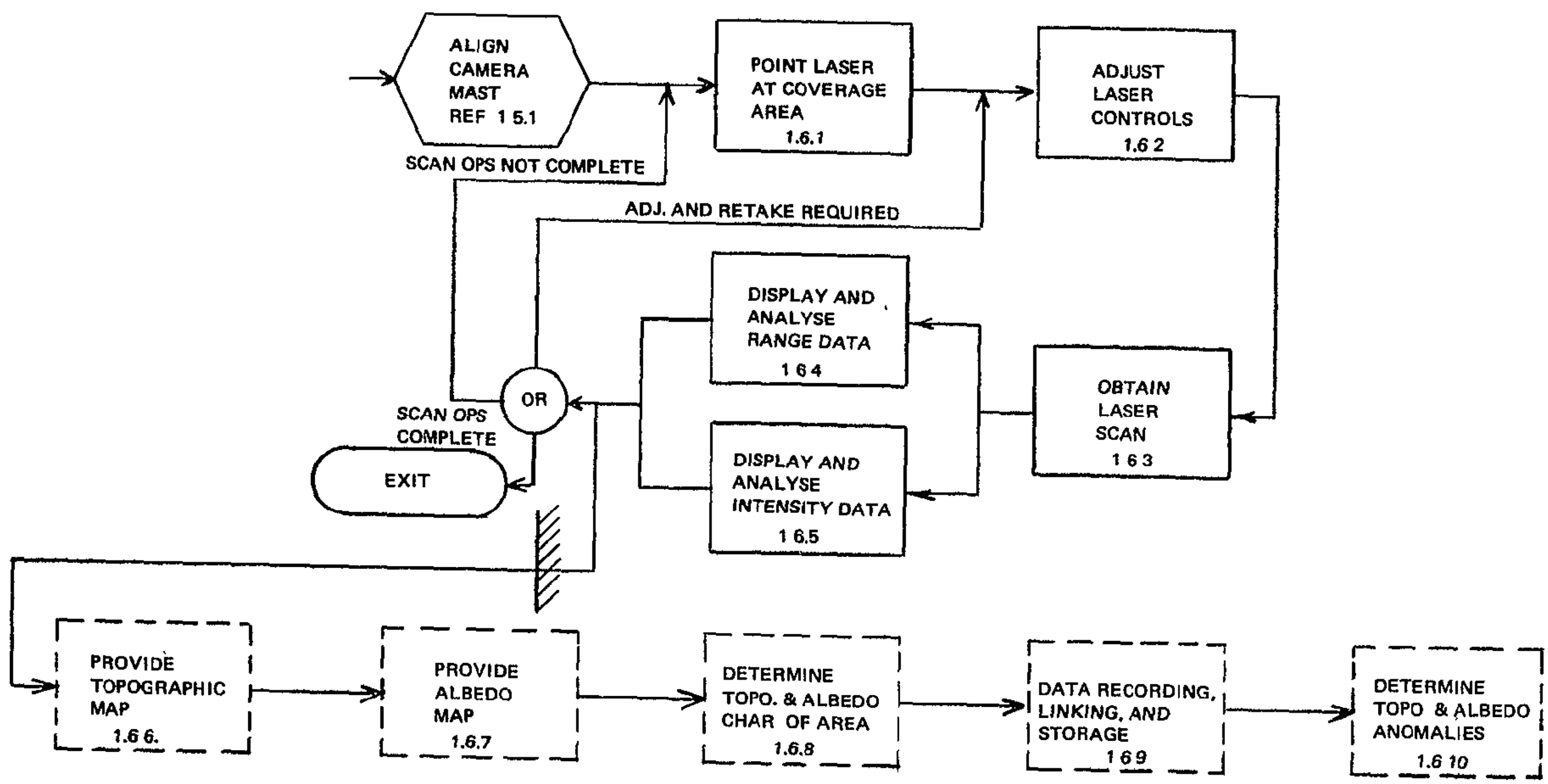

Fig. 15. Major Sequence 1. 6 Laser Scanning

1.6 LASER SCANNING OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 6.1 POINT LASER AT COVERAGE AREA	Command Az, El control of laser device to area of desired scan	1) Desired co-ordinates (with respect to LRV) of scan area 2) Az, El read-out of present pointing direction 3) Sun angle	1) Generation of necessary pointing angles for scanner 2) Driving of Az, El readouts 3) Compute sun glare avoid-ance	1) Panorama of area sur-rounding vehicle includ-ing desired scan area 2) Az, El read-outs present pointing direction	1) Determination of Az, El command	1) Uplink com-mands for scanner Az, El alignment	Required laser coverage may be less than 360°
1 6 2 ADJUST LASER CONTROLS	Adjustment of laser device con-trols for opti-mization of laser quality	1) Desired set-tings for laser controls as determined from analysis of panorama or previous laser scan data	1) Driving of laser controls displays	1) Laser control settings	1) Analyze pan and/or laser data to de-termine re-quired settings for laser controls 2) Provide uplink commands	1) Uplink laser control commands	
1 6 3 OBTAIN LASER SCAN	Reception of laser scan data	1) Laser scan data 2) Laser con-trols data	1) Assy and storage of scan data 2) Ref. 1 6 2	1) Laser con-trols data	1) Monitor bit streams and controls data for proper operation	1) Uplink scan command	
1.6 4 DISPLAY AND ANALYZE RANGE DATA	Display range data on CRT to determine quality	1) Laser scan data	1) Driving of range display from assem-bled and stored scan data	1) CRT display of range data	1) Analyze dis-play for quality of ranging data 2) Determine re-quired changes to scanner control settings	1) Changes to laser control settings	This is CRT dis-play of range data to obtain info on the dynamic range of the data
1 6 5 DISPLAY AND ANALYZE ALBEDO DATA	Display Albedo data on CRT to determine quality	(1 6 4)	1) Driving of albedo display from assem-bled and stored scan data	1) CRT display of intensity data	(1.6 4)	(1 6 4)	(See comments on 1 6 4)

LASER SCANNING (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 6.6 PROVIDE TOPO-GRAPHIC MAP	Provide isograms of local topo-graphic data	1) Range data from laser scans 2) Laser pointing data	Generation of programs from ranging and pointing data	1) Isogram of local topography	1) Monitoring of proper execu-tion of sequence	None	
1 6 7 PROVIDE ALBEDO MAP	Provide isograms of local albedo data	1) Intensity data from laser scans 2) Laser point-ing data	Generation of isograms from intensity and pointing data	1) Isogram of local albedo	(1 6 6)	None	
1 6 8 DETERMINE TOPO AND ALBEDO CHARACTERISTICS OF AREA	Analysis of ac-cumulated data	• Isograms of 1 6 6 and 1 6 7	• Logging, recording and storing of data	• Tabulation of subject data	Analysis of iso-grams for subject data and trend indications	None	
1 6 9 DATA RECORDING, LINKING, AND STORAGE	Recording of topo and albedo data vs seleno-graphic position, time, features, etc	• Tabulations of 1 6. 8	(1 6 8)	• Tabulation of tagged data	• Identify data tagging factors	• Data tagging factors	(See note 1 2 2 3)
1. 6. 10 DETERMINE TOPO-GRAPHIC AND ALBEDO ANOMALIES	Analysis of cur-rent data in light of previous data	• Topographic and albedo data both pre-vious and current	• Update statistical model • Determine deviation of new data from model • Store info on anomalies	• Tabulation of anomalies	• Examination of current scan data and correlation with previous data	None	Anomalies will be defined as significant devia-tions of current data from norm of previous data

H. EARTH DISTANCE RANGING MAJOR SEQUENCE (1.7)

1. Objective.

The objective of this sequence is to meet all requirements of the Earth Distance Ranging Experiment related to the LRV.

2. Scope.

It includes:

(1) On the LRV· pointing of the retroreflector toward the earth.

(2) On earth: coordinating Laser Tracking Activities.

3. Assumption

(1) The vehicle is stationary and will remain so for duration of the sequence.

(2) The vehicle attitude and earth pointing direction have been calculated by Navigation/Guidance Operations.

(3) Pointing of the retroreflector will not interfere with other science operations at the station (e.g., TV or Fax imaging, laser scanning ops, or gravimetry).

(4) Laser tracking stations are considered mission independent support organizations and are not treated herein.

4. Discussion.

Earth Distance Ranging (Fig. 16) will utilize a reflecting surface on the LRV which will be utilized by earth-based laser ranging stations. The reflecting surface will be steerable to allow pointing of the device toward the earth so that ranging activities may be conducted independently of vehicle attitude.

Since pointing of the retroreflector is critical to success of the experiment, this sequence can only be accommodated while the vehicle is stationary. Typically the sequence would be accomplished during the Visual Terrain Assessment experiment.

Earth look-angles and associated retroreflector steering commands will be determined from the values of vehicle attitude supplied by navigation. The earth look-angle can be verified through video imaging.

Activities within the sequence include pointing the retroreflector and coordinating the ranging requirements of the earth-based ranging station with other LRV activities.

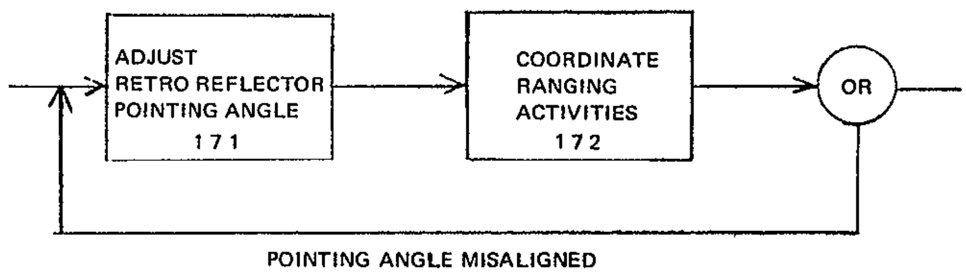

Fig. 16. Major Sequence 1.7 Earth Distance Ranging

1 7 EARTH DISTANCE RANGING	*MOC PROFILE (ACTIVITIES ON THE EARTH)*						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.7 1 ADJUST RETRO REFLECTOR POINTING ANGLE	Align retroreflector pointing angle to moon/earth line	1) Azimuth, elevation angle readouts from retroreflector 2) Ephemeris data 3) Vehicle attitude 4) Vernier pointing request from laser tracking station	1) Driving of display from raw data 2) Computation of required adj of retroreflector pointing angle 3) Sun line and local lunar vertical in vehicle coordinates 4) Moon-earth line in vehicle coordinates	1) Az, El of retroreflector 2) Δ ∢ S to moon-earth line 3) Reflector angles relative to moon	1) Generation of retroreflector pointing angle commands	1) Retroreflector azimuth, elevation command sequences	TV might be utilized to verify earth-moon pointing angles
1.7 2 *COORDINATE RANGING ACTIVITIES*	Indicate to laser *tracking station* that vehicle is stationary and retroreflector is pointed for ranging sequence to commence	1) Indication that *retroreflector* is pointed	None	None	1) Monitor LRV *activities to* notify laser tracking station when vehicle motion will commence 2) Monitor ranging for benefit *of LRV ops*	1) LRV status to *tracking station* 2) Laser ranging progress to LRV ops 3) LRV selenographic position provided to laser tracking station 4) Obtain and output vehicle elevation per laser tracking station	

I. SAMPLING (1.8)

1. Objective.

The objectives of this sequence are:

(1) To acquire, from the surface area selected during reconnaissance (Fig. 5), the best available set of samples of lunar surface material.
(2) To prepare these samples for viewing.
(3) To deliver the samples to the storage system and/or the viewing stage.
(4) To provide data bank services for identification of samples, their characteristics and location.

2. Scope

It includes:

(1) Potential use of all sample acquisition tools carried by the LRV.
(2) Revision of reconnaissance selections through closeup photography.
(3) All acquisition activities up to and including delivery of sample to sample viewing stage and/or analysis instruments.

3. Assumption.

The vehicle is stopped with sample point(s) within range of manipulator.

4. Discussion.

The sampling operation (Fig. 17) will consist of chipping, coring, scooping, and/or retrieval. Operation of the manipulator will be conducted in slewing and vernier positioning modes as discussed in Magnetometry operations (Fig. 6).

It is assumed, from the vehicle baseline, that the manipulator device permits interchangeability of operating heads (or tools). Selection of the proper head (i.e., chipper, scoop, etc.) will be made in real time from analysis

of TV pictures and the requirements for sampling. The interchange operation consists of stowing and removing the attached head followed by inserting and unstowing the desired head.

Video aids will be utilized at all times to monitor all manipulator operations. Computer programs will be utilized to provide video pointing commands and manipulator steering to expedite performance of the sequence.

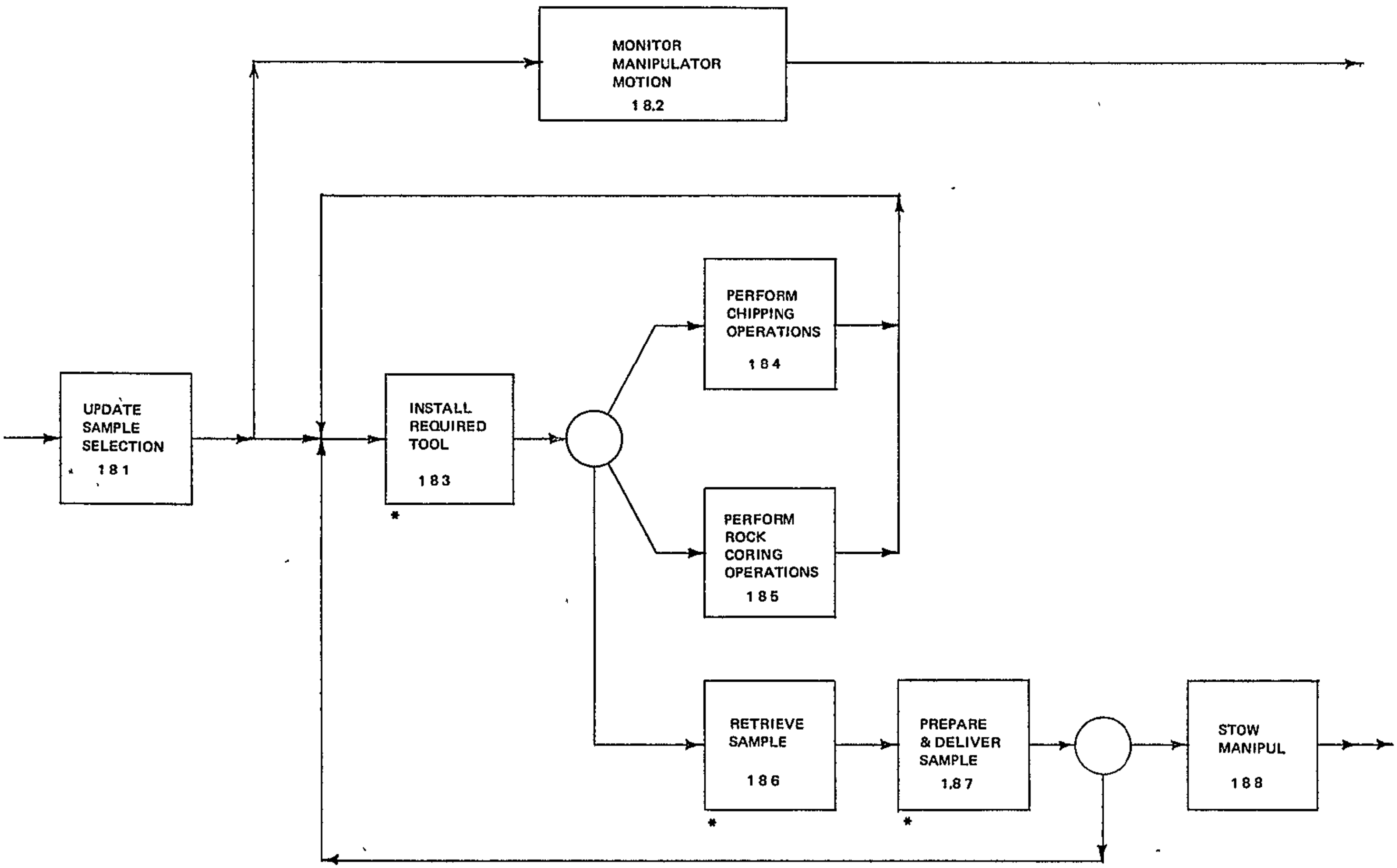

Fig. 17. Sample Acquisition 1.8

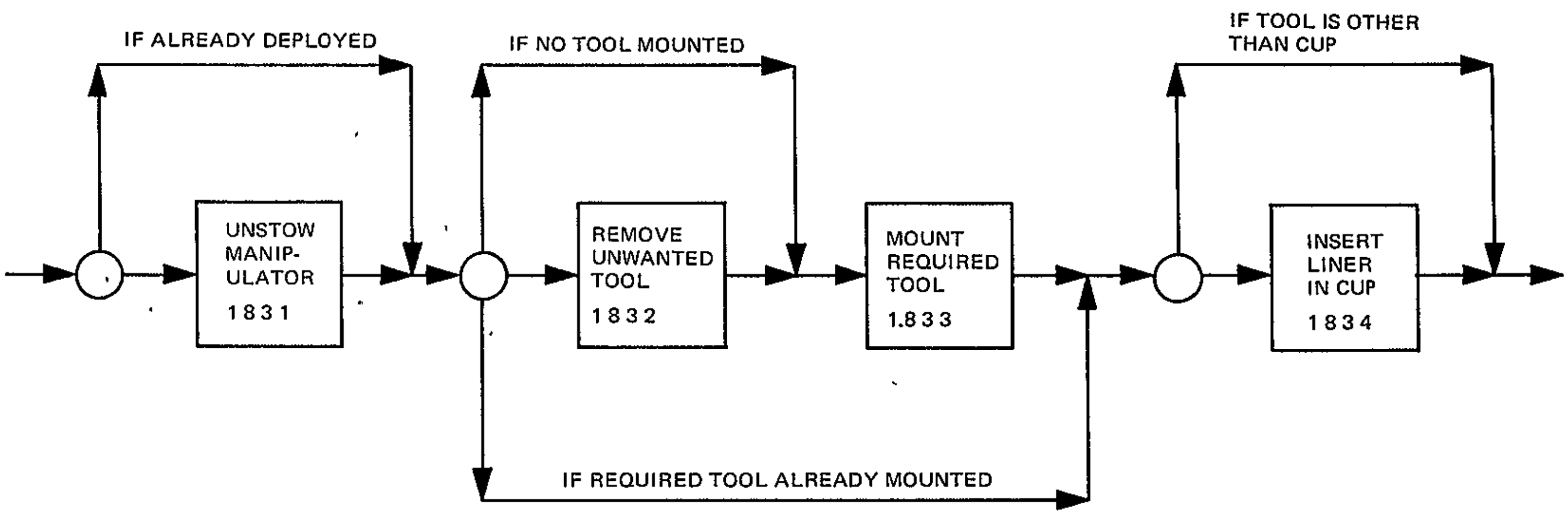

Fig. 18. Minor Sequence 1.8.3 Install Required Tool

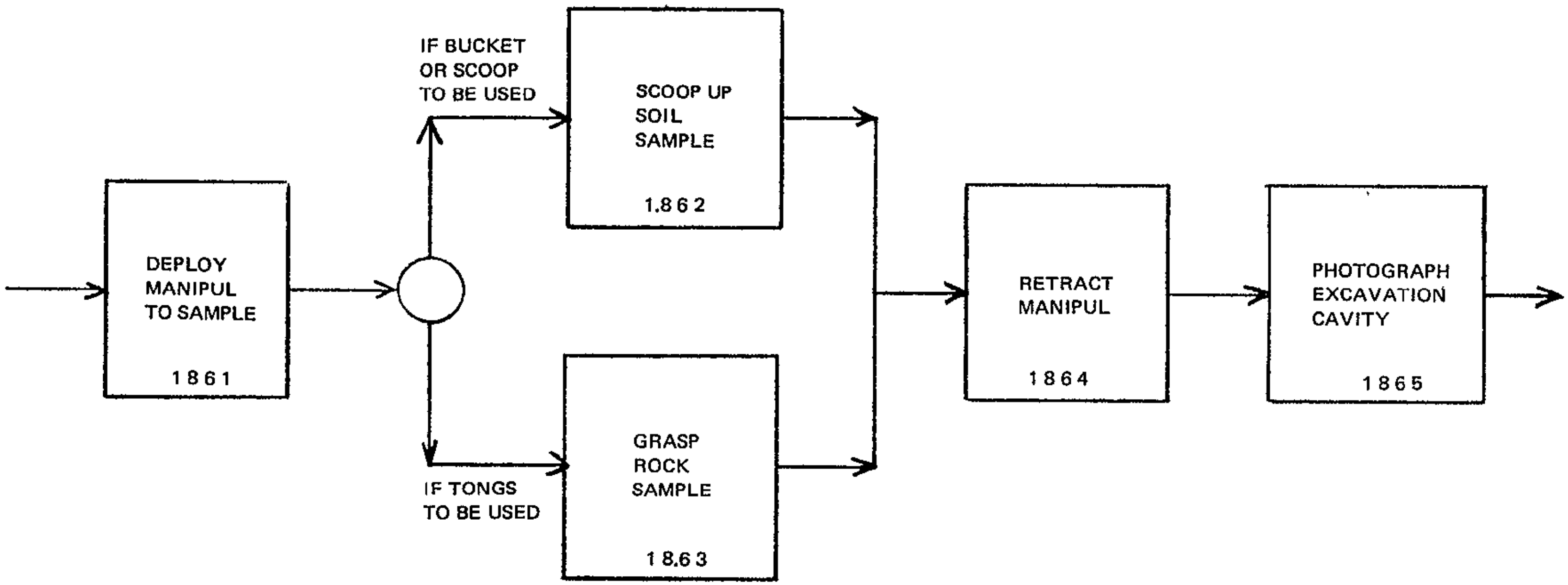

Fig. 19. 1.8.6 Retrieve Sample

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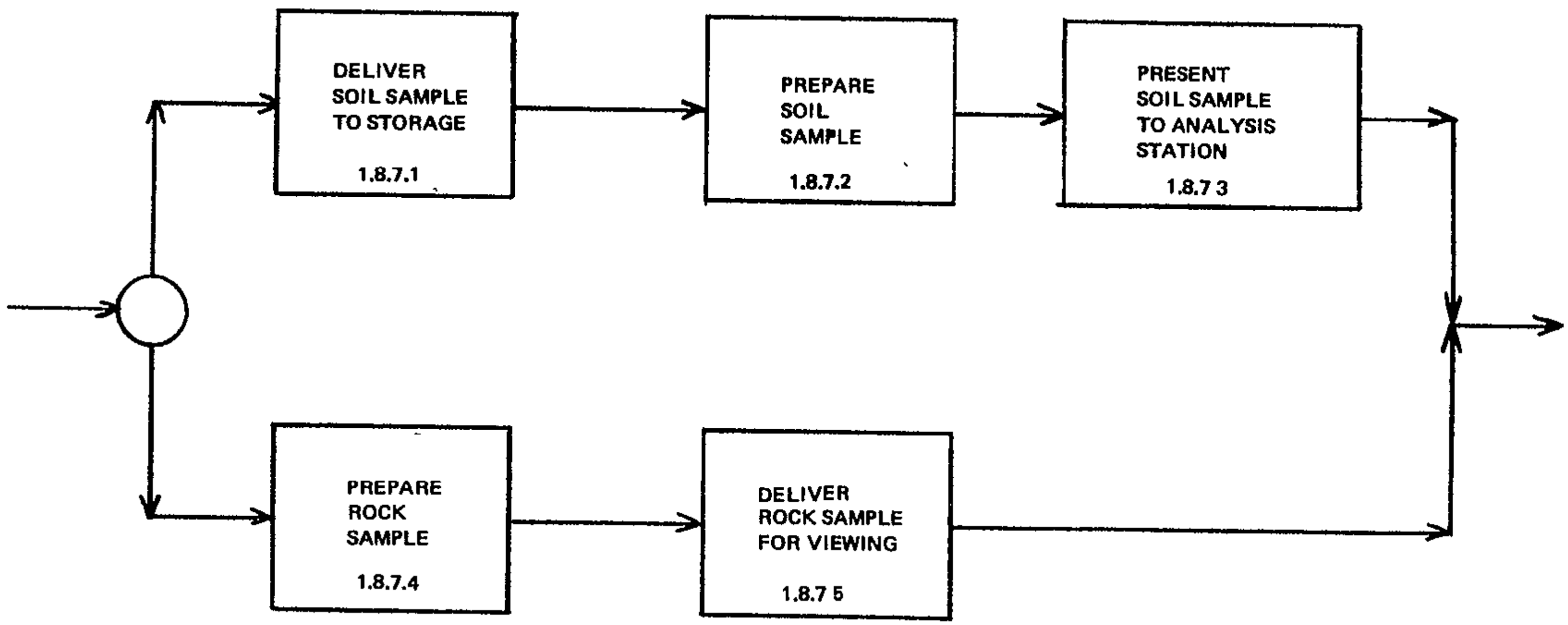

Fig. 20. 1.8.7 Prepare and Deliver Sample

1 8 SAMPLE ACQUISITION	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 8.1 UPDATE SAMPLE SELECTION 1 8 1 1 PERFORM FORE-GROUND SURVEY (Reference 1 5 4 1 thru 1 5 4 5	Provide maximum-resolution nearly-vertical stereo photography of potential zone of sampling at this station						
1 8 1 2 UPDATE SELECTION OF SAMPLING POINTS (Analogous to 1.5 5)	Revise choice or number of sampling points or improve accuracy of their definition	Displays from 1 8 1 1, including 1) TV pictures of foreground 2) Sample position and line-of-sight from recon 3) Range and azimuth overlay	Light-pen display Computation of sample coordinates in 3-D space	Display of information received plus overlay (upon foreground TV) of revised sampling points	Scan foreground pix for best sampling points Compare above vs those set at recon (1.1) 1) Select sampling points 2) Select manipulator 3) Select tool to be used	Selected 1) Sampling points 2) Manipulator 3) Tool to be used Update data bank for this sample	
1 8 2 MONITOR MANIPULATOR MOTION	Provide TV coverage of specified manipulator, tracking its motion	Identification of manipulator to be tracked Drive coordinate of manipulator Projected future motion of manipulator Sun angle TV/TM data	Camera pointing Glare avoidance Future motion overlay TV/TM conversion	TV pictures of manipulator Future motion overlay Manipulator ident Manipulator coords Sun angle	Monitor TV pix for indications of impending trouble Command manip halt when req'd Identify changes in designated subject, when req'd	Camera pointing and adjusting commands Manipulator halt commands	

1.8.3 INSTALL REQUIRED TOOL	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.8.3.1 UNSTOW MANIPULATOR	Free manipulator from transport security lock-up	1) Identity of manipulator to be used 2) Status of manipulator re stowage TV/TM	Control of manipulator motion TV/TM	Identity of manipulator to be used Stowage status of manipulator Projected motion TV/TM	Command unstowage Approve projected motion path Monitor motion	Unstowing commands	Overlay projected motion path onto TV
1.8.3.2 REMOVE UNWANTED TOOL	Deploy manipulator storage position of old tool Insert old tool into receptacle Unlock detent Withdraw manipulator	Identity of required tool Identity of present tool Manipulator drive coord TV/TM	Control of manipulator motion TV/TM	Identity of required tool Identity of present tool Manipulator position coord Projected motion TV/TM	Command tool removal Approve projected motion path Monitor motion	Manipulator motion commands Detent commands	Overlay projected motion path onto TV
1.8.3.3 MOUNT REQUIRED TOOL	Deploy manipulator to storage position of new tool Insert head into new tool Lock detent Withdraw manipulator	Identity of required tool Manipulator drive coord TV/TM	Control of manipulator TV/TM	Identity of required tool Manipulator position coord Projected motion TV/TM	Command tool mounting Approve projected motion path Monitor motion	Manipulator motion commands Detent commands	Overlay projected motion path onto TV
1.8.3.4 INSERT CUP LINER	Place anti-contamination liner inside sample-gathering cup	Cup position coordinates TV/TM	None TV/TM	TV/TM	Check absence of cup liner in cup Command insertion of cup liner Monitor action	Cup liner insertion command	

1 8,4 PERFORM CHIPPING OPERATIONS	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1. 8. 4 1 TAKE PRE-CHIPPING REFERENCE PICTURES (Ref 1 5 4 1 thru 1. 5 4 3	Provide photo reference for future comparison, of 1) Sample source 2) Litter surface			TV picture of sample surface undisturbed	Identify area to be photographed Approve reference photo	Camera pointing commands	
1. 8 4. 2 DEPLOY MANIPULATOR TO STANDOFF POSITION	Transfer chipper to position in front of planned fracture-point	Manipulator drive coordinates Coordinates of desired chipping point Standoff dimension	Manipulator motion control Projected future motion of chipper	Coordinates of 1) Desired fracture 2) Chipper tool TV pictures of chipper	Initiate advance to standoff Monitor motion of chipper	Manipulator motion commands	
1 8 4. 3 ADJUST ORIENTATION OF CHIPPER	Align axes of chipper with fracture-plane	Manipulator drive coordinates Tilt and slope of desired fracture plane	Manipulator motion control Projected future motion of chipper Projected future aspect of chipper	TV pictures Projected motion	Specify tilt angles desired Monitor motion	Manipulator motion commands	
1. 8. 4. 4 ADVANCE CHIPPER INTO CONTACT	Close gap between chipper tool and sample surface	Manipulator drive coordinates Target coord. of sample face Chipper contact force	Manipulator motion control Projected future motion of chipper Clearance distance	TV pictures Projected motion Clearance distance Contact force	Initiate closure Monitor motion Override control as required	Manipulator motion commands	
1. 8. 4. 5 PERFORM CHIPPING	Repetitive hammering at fixed rate	Chipper deceleration Manipulator drive coord.	Compute dynamic resistance Detect lateral jump of chipper	Impact momentum Blows/second Lateral jump of chipper Advance of chipper	Monitor TV pictures, sample resistance, chipper jumpout Adjust momentum and chipping rate	Commands to adjust chipping rate and momentum	

PERFORM CHIPPING OPERATIONS (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 8 4 5 DETECT CHIPPAGE AND CHIP LOCATIONS	Determine source and fallen position of rock chip	TV picture data of two kinds 1) Prior to fracture 2) Subsequent to fracture of two subjects 1) Sample source (rock face) 2) Litter surface	a) Convert TV/telemetry data into display b) Correlate corresponding timewise anterior and posterior picture c) Difference (b) to determine chip outline d) Superimpose outline of chip into (a)	TV pictures of source and litter areas a) Anterior (timewise) b) Posterior (timewise) c) Posterior, with chip outlined	Confirm appropriateness of automatic recognition of chip pattern	Position coordinates of fallen chip	Chip position found by "solarization" differencing techniques
1 8 4 6 RETURN CHIPPER TOOL TO RETRACTED POSITION	Drive chipper to stand-off position in front of storage location	Target location of chipper storage location Manipulator drive coordinates	Motion control to reposition chipper Sun glare avoidance Chipper coordinates	Sun avoidance angle Chipper coordinates	Monitor TV pictures of chipper motion	Command halt in event of anomaly	None
1 8 5 1 DEPLOY MANIPULATOR TO STANDOFF POSITION (Reference 1 8 4 2)	Transfer coring device to position adjacent to and clear of contact position	←		REF 1 8 4 2		→	Assumes rock coring device is mounted on manipulator
1 8 5 2 ADVANCE CORING DEVICE INTO CONTACT (Reference 1 8 4 4)	Close gap between coring device and sampling surface	←		REF 1 8 4 4		→	
1 8 5 3 PERFORM DRILLING	Rotary drilling activities	Drilling speed, resistance, advancement TV/TM data	TM conversion TV/TM conv	Drilling speed, resistance, advancement TV pictures	Initiate drilling Monitor performance Adjust drilling parameters	Drilling parameter — setting commands	

RETRIEVE SAMPLE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.8.5.4 WITHDRAW CORER	Remove drill from hole and extract sample	Drill coordinate and resistance TV/TM data	TM conversion	Drill coordinate Resistance to extraction	Initiate extraction	Extraction commands	
1.8.5.5 RETURN CORING DEVICE TO RETRACTED POSITION (Reference 1.8.4.6)		←		REF 1.8.4.6		→	
1.8.6.1 DEPLOY MANIPULATOR TO SAMPLE	Drive manipulator to standoff position in front of sample location	Target location of sample Manipulator drive coordinates	Motion control to reposition tool Sun glare avoidance Tool coordinates	Sun-avoidance angle Tool coordinates	Monitor TV pictures of tool motion	Command halt in event of anomaly	None
1.8.6.2 SCOOP UP SAMPLE							
1.8.6.2.1 ORIENT CUP FOR SAMPLE SCOOPING	Tilt cup backward re scooping axis	Cup tilt angle data	Convert TM into cup angle	Cup tilt angle	Monitor TV pictures	Command halt in event of anomaly	
1.8.6.2.2 ADVANCE CUP TO GROUND CONTACT	Bring cup into contact with ground	Manipulator drive coordinates	Coordinates of cup Standoff distance from ground	Coordinates of cup Standoff distance from ground	Monitor TV pictures	Command halt in event of anomaly	
1.8.6.2.3 INSERT CUP BY PITCHING	Rotate cup about its scooping axis	Manipulator drive coordinates Manipulator drive torques	Cup position "Biting" force	Cup position "Biting" force	Monitor TV pictures	Command halt in event of anomaly	
1.8.6.2.4 WITHDRAW CUP	Extract specimen from its environment	TV/TM data	Convert TV/TM to pictures	TV pictures of filled or loaded cup	Monitor TV pictures	Command halt in event of anomaly	
1.8.6.2.5 CHECK SUITABILITY OF CUP LOAD	Determine need for repeated trial	None	None	Same as above (1.8.6.2.4)	Study TV pictures Decide suitability of load	Suitability of load	
1.8.6.3 GRASP SAMPLE							

RETRIEVE SAMPLE (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.8 6 3 1 OPEN TONGS	Extend jaw of tongs	Tongs-jaw articulation	Convert TM into readable data Tongs-jaw motion control	Tongs opening (mouth size)	Monitor TV pictures	Tongs-jaw motion control	
1 8 6 3 2 ADVANCE TONGS TO CONTACT SAMPLE	Bring tongs into contact with sample	Manipulator drive coordinates	Compute separation between tongs and sample	Separation between tongs and sample	Monitor separation visually		
1 8 6 3 3 CLOSE TONGS AROUND SAMPLE	Contract tongs-jaw	Tongs-jaw articulation display data Tongs-jaw articulation force data	Convert TM into readable data Detect jaw-force	Tongs-jaw opening Tongs-jaw force	Monitor closure	Tongs-jaw motion control	
1 8 6 3 4 LIFT TOOL PLUS SAMPLE	Raise tool sufficiently to permit assessment of grip	Manipulator drive coordinates	Convert manipulator drive coordinates into tool position coordinates	Tongs position coordinates TV pictures	Monitor TV	Manipulator motion control	
1 8 6 3 5 CHECK "GRASP" SECURITY	Test suitability of tongs grip	None	None	TV pictures from above (1 8 6 3 4)	Study TV pictures for grasp unsuitability Issue commands required for sample setdown and pickup	Commands for sample setdown and pickup	Initial grasp may be unsatisfactory and require setdown and repeated pickup
1 8 6 4 RETRACT MANIPULATOR AND SAMPLE	Retrieve sample to vicinity of vehicle	Manipulator drive coordinates	Convert manipulator drive coordinates into tool position coordinates (same as 1 8 6 3 4)	Tongs position coordinates TV pictures	Monitor TV	Manipulator motion control	
1 8 6 5 PHOTOGRAPH EXCAVATION CAVITY	Record soil conditions after extraction	TV/TM data	Convert TV/TM data into display pictures	TV picture	None	None	May require special illumination

PREPARE AND DELIVER SAMPLE OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 8 7.1 DELIVER SOIL SAMPLE TO STORAGE SYSTEM	Transfer sample	See below					
1.8 7 1 1 PRESENT EMPTY CONTAINER IN BUFFER STORAGE	Cause available container in storage to be stationed at entrance	Buffer storage train position TV/TM data	Inter-relate sample with buffer storage train movement Motion control TV/TM conversion	Position of subject samples in buffer storage TV pictures of container	Confirm (via TV) emptiness of container presented	Motion control of buffer storage train	Advance buffer storage train
1 8.7.1 2 TRANSFER SAMPLE FROM SCOOP OR CUP INTO STORAGE CONTAINER	Pour soil sample from scoop into buffer container	Scoop attitude data TV/TM data	Motion control TV/TM conversion	Scoop attitude TV pictures of pouring	Monitor pouring process, spillage, and container filling	Motion control of scoop pouring	
1.8.7.1 3 RETRACT MANIPULATOR	Remove empty scoop	Manipulator drive coordinates Target position coordinates TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position coordinates TV pictures	Monitor motion	Motion control of manipulator	Automatic control Automatic tracking
1 8 7 2 PREPARE SOIL SAMPLES FOR VIEWING	Level-off top of soil sample to present uniform height for viewing	Screed drive coordinates TV/TM data	TV/TM conversion	Screed position coordinates TV pictures	Initiate screeding Monitor screeding and spillage	Screed motion commands	
1 8 7 3 PRESENT SOIL SAMPLES FOR VIEWING	Deliver sample container to viewing stage	Coordinates of sample container		Sample container coordinates	Initiate delivery	Buffer system advancement command	
1 8 7 4 PREPARE ROCK SAMPLES FOR VIEWING							
1 8 7 4 1 TRANSFER TV MONITOR ASSIGNMENT TO MANIPULATOR "B"	Shift monitoring to "other" manipulator	Data re which manipulator is being monitored	None	Indicator showing which manipulator is being monitored	Command change Confirm accomplishment of change in subject	Command to change subject of TV monitoring	Sample remains in manipulator

PREPARE AND DELIVER SAMPLES (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH) SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 8 7 4 2 INSTALL DUST REMOVAL TOOL ON MANIPULATOR "B"	Insert manipulator into dust removal tool	←		REFERENCE 1 8 4		→	Presumes manipulator "B" to be free of other tools
1 8 7 4 3 DEPLOY MANIPULATOR "B" TO VICINITY OF MANIPULATOR "A"	Approach sample with duster device	Manipulator drive coordinate TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position TV pictures	Monitor manipulator motion	Motion control of manipulator	
1 8 7 4 4 COMMENCE ROTATION OF DUST REMOVAL DEVICE	Start spin-up of duster	Spin data TV/TM	TV/TM	Spin rate of dust removal device TV pictures	Monitor motion of dust removal device	Command to start spin-up	Presumes dust removal uses spin
1 8 7 4 5 BRUSH MANIPULATOR "B" ACROSS MANIPULATOR "A"	Dust sample in "A" with device in "B"	Manipulator drive coordinates TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position TV pictures	Monitor dust removal	Motion control of manipulator	
1 8 7 4 6 ROTATE TONGS (FRESH SURFACE)	Present other surfaces to be dusted	Manipulator drive coordinates TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position TV pictures	Monitor sample attitude	Desired rotation angle Motion control	If sample is in cup, this presumes tongs are brought to cup
1 8 7 4 7 TURN OFF ROTATION OF DUST REMOVAL DEVICE	Shut down dust removal device	TV/TM data	TV/TM conversion	TV pictures	Monitor spin rate of dust removal device	Command to turn off rotation of dust removal device	
1 8 7 4 8 TRANSFER TV MONITOR ASSIGNMENT BACK TO MANIPULATOR "A"	Shift monitoring back to sample	Data re which manipulator is being monitored TV/TM data	TV/TM conversion	Indicator showing which manipulator is being monitored TV pictures	Confirm accomplishment of change in TV subject matter	Command to change subject of TV monitoring	

PREPARE AND DELIVER SAMPLES (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.8.7 5 DELIVER ROCK SAMPLE FOR VIEWING	Set of operations to place sample in viewing position	←		SEE BELOW		→	
1 8.7 5.1 TRANSPORT SAMPLE TO VIEWING STATION	Reposition sample within storage system to the viewing station	Buffer storage train position	Inter-relate sample identity with buffer storage train movement Motion control	Position of subject sample in buffer storage		Motion control of buffer storage train	Advance buffer storage train
1.8.7 5 2 DEPLOY SAMPLE HOLDER TO POINT ABOVE VIEWING STAGE	Shift manipulator location to be over stage	Manipulator drive coordinates TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position TV pictures	Monitor sample motion	Motion control of manipulator	
1.8.7 5.3 ADJUST ORIENTATION OF SAMPLE	Rotate sample to optimum visibility	Manipulator drive coordinates TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position TV pictures	Monitor sample attitude	Motion control of manipulator	
1.8.7.5.4 LOWER SAMPLE ONTO STAGE	Lay sample on stage	Lay sample on stage	Lay sample on stage	Lay sample on stage	Monitor sample position	Monitor sample position	
1 8 7 5 5 RELEASE MANIPULATOR GRASP	Unclasp manipulator	Grasping tool articulation data TV/TM data	TV/TM conversion	Grasping tool articulation TV pictures	Monitor closure status of grasping tool	Command to release grasp	
1 8 8 STOW MANIPULATOR	Store manipulator and stop TV monitoring	←		SEE BELOW		→	
1 8 8 1 STORE MANIPULATOR	Insert manipulator into seat and lock detent	←		REF 1 8 4 6		→	
1 8 8.2 STOP TV MONITORING	Turn off TV coverage and replace lens cover	Manipulator status TV status	None	TV display manipulator storage status TV status	Initiate command and monitor response	Command to stop TV	

J. VISUAL EXAMINATION OF SAMPLE (1.9)

Objectives

The objectives of this sequence are:

(1) To establish the geological classification of samples presented.

(2) To relate the subject sample with all prior samples examined visually and to detect anomalies.

(3) To make positive recommendations regarding retention, rejection, and further analysis of the subject sample.

(4) To create a photographic record of the sample's visual appearance.

2. Scope

It includes:

(1) Stereo photography

(2) Variable lighting angles

(3) All faces of solid specimens

3. Assumption

(1) The sample examination camera may not be a dedicated device; therefore, it may be necessary to physically reposition the camera in order to obtain the required imaging.

(2) Sample is on viewing stage and sufficient illumination is available.

4. Discussion

Sample Visual Examination (Fig. 21) will be accomplished utilizing a high resolution, medium magnification (1×10^1) TV imaging system. Data to be accumulated on each sample includes sizing, color, surface roughness, texture, etc. In order to obtain this information the sample viewing port, lighting angles will require changing and various color filters will require positioning. This sequence provides those activities necessary for the preceeding with the operation of the sample examination camera.

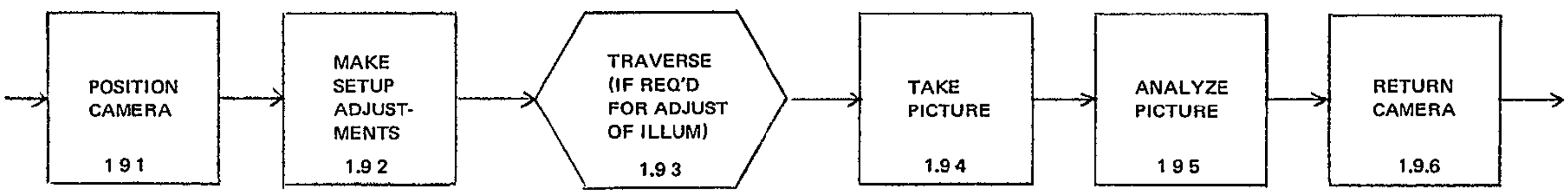

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Fig. 21. Major Sequence 1.9 Visual Examination of Sample

VISUAL EXAMINATION OF SAMPLE OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC *PROFILE*	INFORMATION *RECEIVED*	INFORMATION *PROCESSING*	INFORMATION *DISPLAY*	HUMAN *ACTIVITIES*	INFORMATION *TRANSMITTED*	REMARKS
1.9 1 POSITION CAMERA (AT SAMPLE VIEWING STATION)	Reposition TV camera to permit viewing samples	Camera drive coordinates	TM conv.	Camera position coordinates	Initiate deployment Monitor deployment	Camera motion commands	
1 9.1 1 DEPLOY CAMERA TO STANDOFF POSITION	Shift location of TV camera to standoff position in front of holder	Camera drive coordinates	TM conv	Camera position coordinates	Initiate deployment Monitor deployment	Camera motion commands	
1.9.1 2 *INSERT CAMERA INTO HOLDER*	Advance TV camera into holder receptacle	Camera drive coordinates	TM conv	Camera position coordinates	Confirm readiness for insertion Command insertion	Camera motion commands	
1 9 1 3 LOCK CAMERA INTO HOLDER	Secure camera rigidly	Detent lock status data	TM conv	Detent lock status	Command lockup	Detect lock commands	
1.9 2 1 SHIFT FOCAL LENGTH	Change effective focal length of camera	In-situ lens identity or zoom focal length	None	In-situ lens identity or zoom focal length	Initiate change in focal length	Lens change command	May be achieved by zooming or by lens substitution
1 9 2 2 ADJUST SAMPLE ORIENTATION	Translate and pitch sample to center zone of interest and to vary face presented	TV/TM data viewing stage coordin	TV/TM conversion	TV picture viewing stage coordin	Command shift in sample orientation	Initiate TV picture viewing stage translation and rotation (in pitch) commands	
1 9 2 3 ADJUST SAMPLE ILLUMINATION DEVICES	Change angle of lighting relative to sample	TV/TM data	TV/TM conversion	TV picture	Command angular shift	Commands to adjust sample illumination (rotation about optic axis)	May be mirrors, flash lamps, or sample rotation
1 9 2 4 INTRODUCE SELECTED FILTER	Change filter as required	In-situ filter identity	None	In-situ filter identity	Initiate filter change		
1 9 2 5 ADJUST CAMERA SETTINGS	Adjust height of viewing stage	TV/TM data	TV/TM conversion	TV picture	Adjust focus	Viewing stage height change	
1 9 4 TAKE PICTURE	Record photo-image of sample	TV/TM data	TV/TM conversion	TV picture of sample	Initiate picture-taking	TV picture command	

VISUAL EXAMINATION OF SAMPLE (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 9 5 ANALYZE PICTURE	Identify visual characteristics Measure particle count Recommend disposition	←		SEE BELOW			→
1 9 5 1 IDENTIFY PATTERN TYPE AND VISUAL CHARACTERISTICS	Visually identify pattern and mineralogical properties	TV/TM data	TV/TM conversion	TV picture of sample	Identify visual pattern and mineralogical properties	Visual pattern characteristics	
1 9 5 2 MEASURE PARTICLE COUNT	Determine areal density of particles of given size	TV picture from 1 9 5 1 Pattern type identity from 1 9 5 1	Count particles within specified zones Measure zone area Compute areal density of particles	Particle density for each zone of pattern	Initiate commands for particle count Estimate approximate particle count for check	Commands for particle count	
1 9 5 3 RECOMMEND DISPOSITION	Recommand further analysis or retention of sample	Prior sample visual data	Rank present sample vs prior samples (both those in storage and those rejected) Computer recommendations	Relation of present sample to prior sample Computer recommendations Impact upon resources	Approve or modify computer recommendations	Recommended disposition of sample	
1 9 6 RETURN CAMERA (TO TERRAIN-VIEWING CONDITION)	Restore nominal conditions re camera	←		SEE BELOW			→
1 9 6 1 SHIFT FOCAL LENGTH Ref 1.9 2 1	Change effective focal length of camera	In-situ lens identity or zoom focal length	None	In-situ lens identity or zoom focal length	Initiate change in focal length	Lens change commands	
1 9 6 2 UNLOCK HOLDER	Release holder detent lock	Detent lock status data	TM conversion	Detent lock status	Command holder release	Holder release commands	
1 9 6 3 REMOVE CAMERA FROM HOLDER	Withdraw camera	Camera position data	TM conversion	Camera position coordinates	Command withdrawal	Withdrawal command	
1 9 6 4 RETURN CAMERA TO NOMINAL REST POSITION	Reposition camera at nominal station	Camera position data	TM conversion	Camera position coordinates	Command camera motion	Camera motion command	

K. SOIL MECHANICS (1. 10)

1. Objective

The objective of this sequence is to establish the soil mechanics properties of the lunar material traversed.

2. Scope

It includes the determination of:

(1) Bearing strength
(2) Shear strength in combination with bearing
(3) Trench wall definition and cohesiveness
(4) Impact resistance

3. Assumption

The test site is within range of manipulator and scoop head.

4. Discussion

This sequence (Fig. 22) provides operations necessary for examination of the soil mechanics characteristics of the lunar surface. Activities include inspection of the traverse route for wheel sinkage and rut characteristics, bearing tests with shaped surfaces, and static loading, trenching, and impact tests utilizing the manipulator and scoop head.

Video data will be the prime data source with manipulator motor currents required for loading calculations.

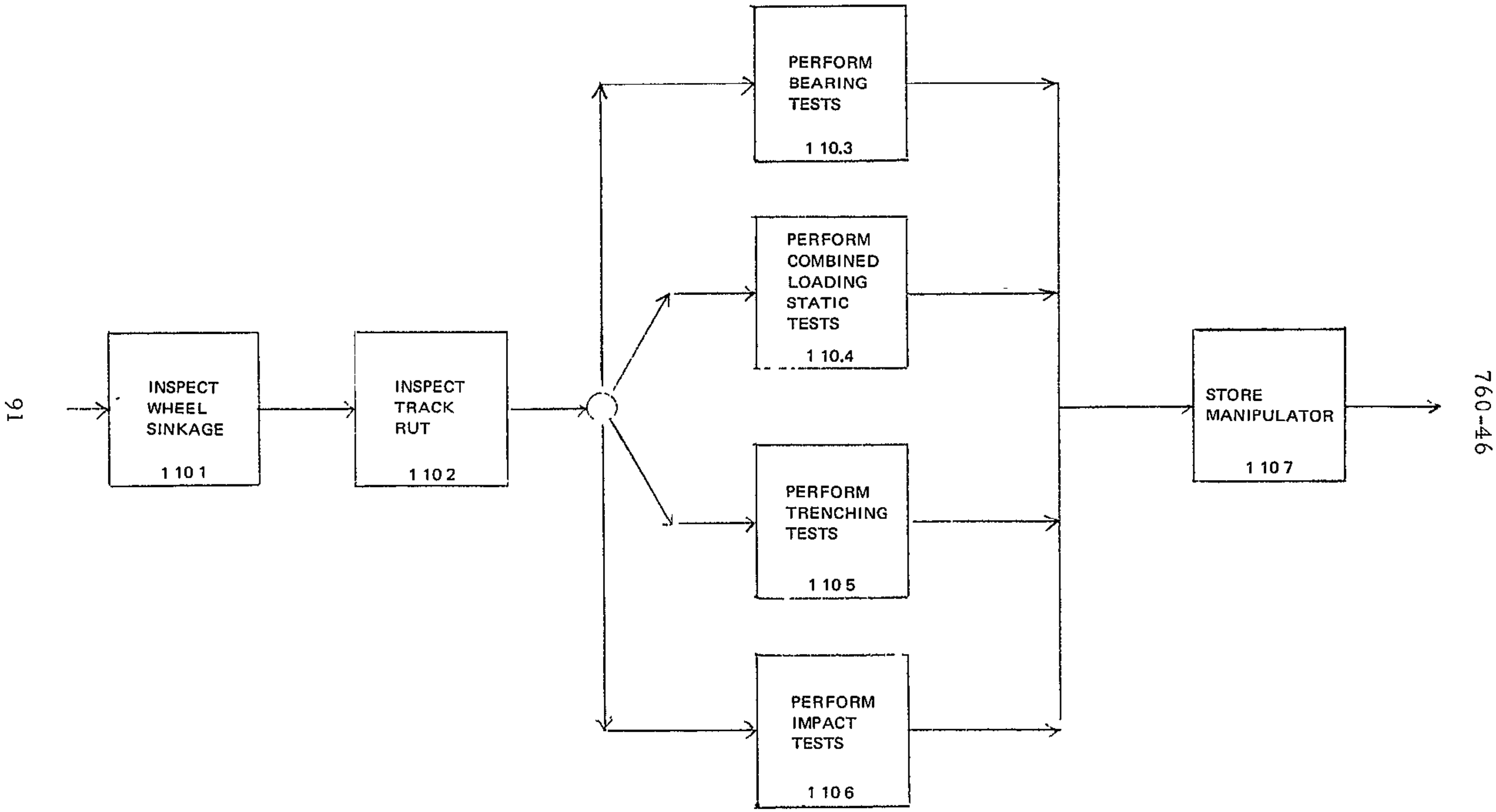

Fig. 22. Major Sequence 1.10 Soil Mechanics

1 10.1 INSPECT WHEEL SINKAGE OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.10.1.1 TRAIN CAMERA ON WHEEL-MIRROR	Point TV at mirror for specified wheel	Identification of wheel to be viewed TV/TM data	Camera pointing control Sunglare avoidance TV/TM conversion	Camera pointing angles Sun angle TV picture thru mirror	Identify wheel to be inspected	Camera pointing commands	
1.10.1.2 ADJUST MIRRORS	Align mirror for best coverage	TV/TM data	TV/TM conversion	TV picture of wheel	Command mirror adjustments	Mirror adjustment commands	
1 10 1.3 ADJUST CAMERA	Focus camera on wheel at treadline	TV/TM data	TV/TM conversion	TV picture of wheel	Command focus	Focus commands	Change in lens focal length may be involved
1 10 1.4 TAKE PICTURES	Record photo image of wheel at treadline	TV/TM data	TV/TM conversion	TV picture of wheel	Initiate picture-taking	TV picture command	
1.10 1 5 ANALYZE DATA	Determine soil mechanics characteristics of ejecta and determine traversibility	TV picture from 1.10.1 4	None	None	Determine soil mechanics characteristics of ejecta and soil traversibility	Traversibility of soil	
1.10.2.1 TRAIN CAMERA ON TRACK	Point TV at track (to rear of vehicle)	None	TV/TM conversion	TV picture of vehicle track	Command pointing	Camera pointing commands	
1 10 2.2 ADJUST CAMERA	Focus camera on desired section of track	TV/TM data	TV/TM conversion	TV picture of vehicle track	Command focussing	Focussing commands	Change in focal length may be incurred
1.10 2.3 TAKE PICTURE	Record photo-image of track	TV/TM data	TV/TM conversion	TV picture of vehicle track	Initiate picture-taking	TV picture command	
1.10 2.4 ANALYZE DATA	Determine ejecta depth and soil mechanics properties	TV picture from 1.10.2	None	None	Determine ejecta depth and update soil mechanics properties and soil traversibility	Traversibility of soil	

1.10.3 PERFORM BEARING TESTS	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 10.3.1 ASSIGN TV MONITORING TO MANIPULATOR	Shift subject of monitoring to manipulator	←		REF 1 8 3		→	
1.10.3.2 INSTALL SCOOP ON MANIPULATOR	Connect manipulator to scoop	←		REF 1 8.4		→	
1 10 3.3 DEPLOY SCOOP TO FOREGROUND	Shift scoop position	Manipulator drive coordinates TV/TM data	Determine manipulator position Motion control TV/TM conversion	Manipulator position TV pictures	Specify target location of bearing test Confirm deployment to target	Motion control of manipulator	
1 10 3 4 ARTICULATE AND ORIENT SCOOP	Shift scoop attitude	Manipulator drive coordinates TV/TM data	Determine manipulator attitude TV/TM conversion	Manipulator attitude TV pictures of scoop	Specify target attitude of scoop Confirm achievement of target attitude	Motion control of scoop	
1 10 3.5 PERFORM BEARING TEST	Press scoop toward ground	Manipulator drive data Manipulator force data TV/TM data	Determine manipulator position Manipulator force TV/TM conversion	Manipulator position Manipulator force Plot of force vs position TV pictures	Initiate test displacement Terminate test Observe soil mech phenomena	Command to initiate test Command to terminate test	
1 10 3.6 ANALYZE DATA							
1 10.4.1 PERFORM COMBINED-LOADING TEST	Provide set of vertical and horizontal forces on soil via scoop bucket	Manipulator drive force data TV/TM data	Manipulator TM conversion TV/TM conversion	Manipulator forces Ratio of horizontal to vertical forces Plot of force vs position TV pictures	Initiate test loads Terminate tests Observe soil mechanics phenomena	Manipulator force commands	Assumes scoop to be on manipulator and TV monitor to be assigned to manipulator
1 10 4.2 ANALYSE DATA	Determine critical ratio of horizontal to vertical loading	Manipulator forces and displacements from 1 10 4.1	None	None	Determine critical ratio of horizontal to vertical loading	None	

1 10 5 PERFORM TRENCHING TEST	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 10 5 1 DRAG SCOOP TO FORM TRENCH	Reorient, press down, and retract scoop	Manipulate drive coordinate Manipulate force TV/TM data	Determine manip-ulator position Motion control TV/TM conver-sion Calculate forces in scoop	Manipulator position Manipulate force TV pictures	Monitor trench formation	Motion control of manipulator	
1 10 5 2 ANALYZE DATA 1 10 6 PERFORM IMPACT TEST 1 10 6 1 LIFT SCOOP ABOVE SURFACE	Raise scoop	Manipulate drive coordinate Manipulate force TV/TM data	Determine manip-ulator position Motion control TV/TM conver-sion Calculate forces in scoop	Manipulator position Manipulate force TV pictures	Monitor motion of scoop	Motion control of scoop	
1 10.6 2 LET SCOOP FALL (drive downward)	Push down during fall	Manipulate drive coordinate Manipulate force TV/TM data Scoop accelerator data	Determine manip-ulator position Motion control TV/TM conver-sion Calculate forces in scoop Calculate unit forces	Manipulator position Manipulate force TV pictures Scoop accelerator	Monitor motion of scoop	Motion control of scoop	
1 10 6 3 ANALYZE							

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1 10 7 STORE MANIPULATOR	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.10 7 1 DEPLOY MANIPULATOR TO STORED POS.	Retract manipulator and secure	Manipulate drive coordinate Manipulate force TV/TM data Scoop accelerator data	Determine manipulator position Motion control TV/TM conversion Calculate forces in scoop Calculate unit forces	Manipulator position Manipulate force TV pictures Scoop accelerator	Specify target location Monitor motion	Motion control of manipulator	
1 10 7 2 TURN OFF TV MONITORING	Turn TV off	TV/TM data	TV/TM conversion	TV pictures	Confirm disappearance of picture	Command to turn off TV	

L. GAS ANALYSIS (1. 11)

1. Objective

The objectives of this sequence are:

(1) To determine the identity and abundance of particles constituting the lunar atmosphere.

(2) To measure the timewise change in identity and abundance of particles during the sunrise and sunset periods.

(3) To measure space-wise changes in identity and abundance of particles and to correlate these with surface features.

2. Scope

The sequence includes the use of an atmospheric mass spectrometer for particle determination purposes.

3. Assumption

(1) Vehicle is stopped and mechanically inactive.

(2) No deployment of instrument is involved.

4. Discussion

The Gas Analysis Experiment (Fig. 23) is a rapidly conducted routine that requires activation of the mass spectrometer and collection of data for a brief interval. Analysis of data will occur in non-real time.

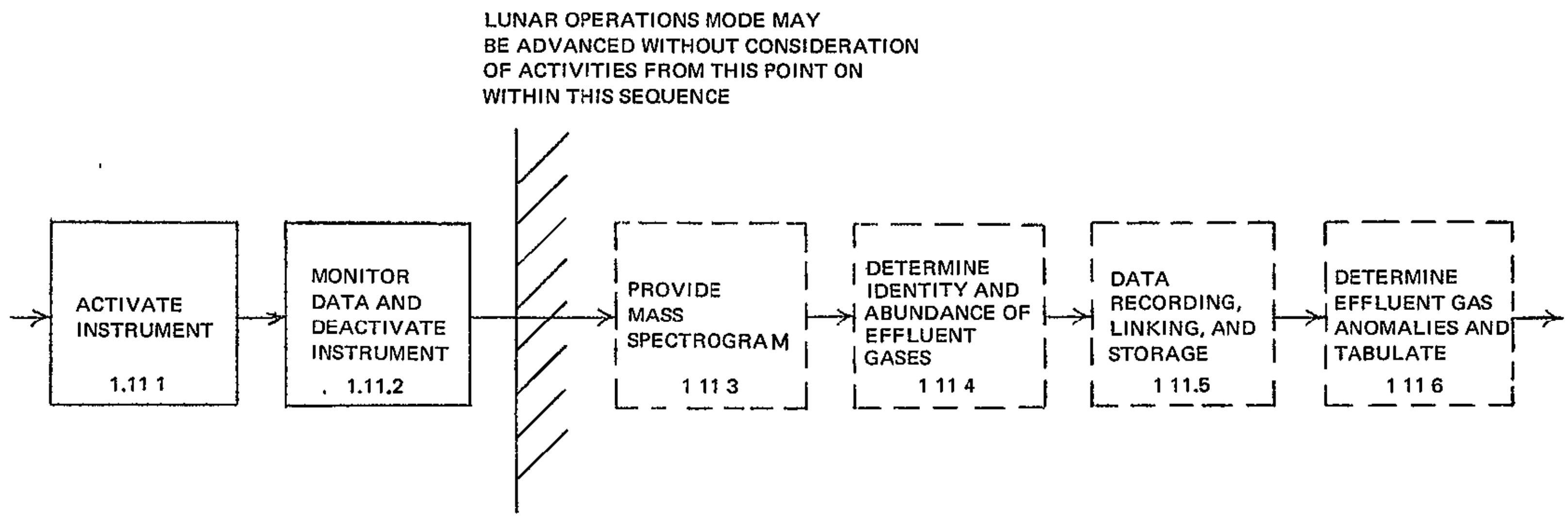

Fig. 23. Major Sequence 1.11 Gas Analysis Operations

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1 11 GAS ANALYSIS	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 11 1 ACTIVATE INSTRUMENT	• Command sent to activate instrument • Downlink telemetry monitored to assure proper activation	• Bus currents • Sensor data	• Computer processing of sensor data to drive sensor display	• Vehicle power data • Sensor output	Monitor data to assure instrument turn-on	Uplink turn-on command for instrument	Data accumulation period very short, therefore necessary to verify turn-on accurately
1 11 2 MONITOR DATA AND DEACTIVATE INSTRUMENT	• Data accumulated • Turn-off command transmitted	• Sensor data	• Computer processing of sensor data to drive sensor display and store	• Sensor output	Monitor data	Uplink turn-off command for instrument	
1 11 3 PROVIDE MASS SPECTROGRAM	• Operate on data	• Stored sensor data	• Computer processing to operate on stored sensor data to provide spectrograph output	• Mass spectrograph (mass vs radius)	• None	• None	
1 11.4 DETERMINE IDENTITY AND ABUNDANCE OF EFFLUENT GASSES	• Operate on data	• Mass spectrograph	None	• Tabulation of gas abundance and identification	• Analyze spectrograph to determine types and abundance of gasses	• None	
1 11 5 DATA RECORDING, LINKING, AND STORAGE	Recording and storing of mass spectrographic data vs selenographic position, time, features, etc	Tabulations and spectrograms of 1 11 3 and 1 11 4	• Labelling and storing all data for subsequent access • Identification of all possible data links	• Tabulation of tagged data	• Identify data tagging factors	• Data tagging factors	(See note 1 2 2 3)

1 11 GAS ANALYSIS (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 11 6 DETERMINE EFFLUENT GAS ANOMALIES AND TABULATE	• Operate on data	• Tabulation from 1 11 4 and previous experiment results	None	• Tabulation of anomalies	• Analyze accumulated date and examine for anomalies	• None	Anomalies will be defined as deviations of current from mean previous data tolerance will be determined

M. SAMPLE DISPOSITION (1.12)

1. Objective

The objectives of this sequence are:

(1) To determine best disposition of each sample (by correlating prior recommendations - visual inspection, mineralogic analysis, chemical analysis - with sampling requirements, mission constraints, and present sampling inventory).

(2) To implement the decision made in the above determination.

2. Scope

It includes all samples, regardless of their type, location, or prior extent of analysis.

3. Assumption

No assumptions are made for this sequence.

4. Discussion

There are three basic dispositions (Fig. 24) which can be utilized for any particular sample. These include jettisoning overboard, transfer to permanent storage, and retention in buffer storage.

The jettisoning function is accomplished by off-loading the sample utilizing the manipulator or buffer jettison mechanism. Transfer to permanent storage is an irreversible function as no sample may be retrieved from the permanent storage facility. Discussion of the permanent storage facility and sampling techniques appears in Sections II-A and II-B. The buffer storage facility has been provided to enable collection of samples and accomplishment of analysis operations at times convenient to the mission operation.

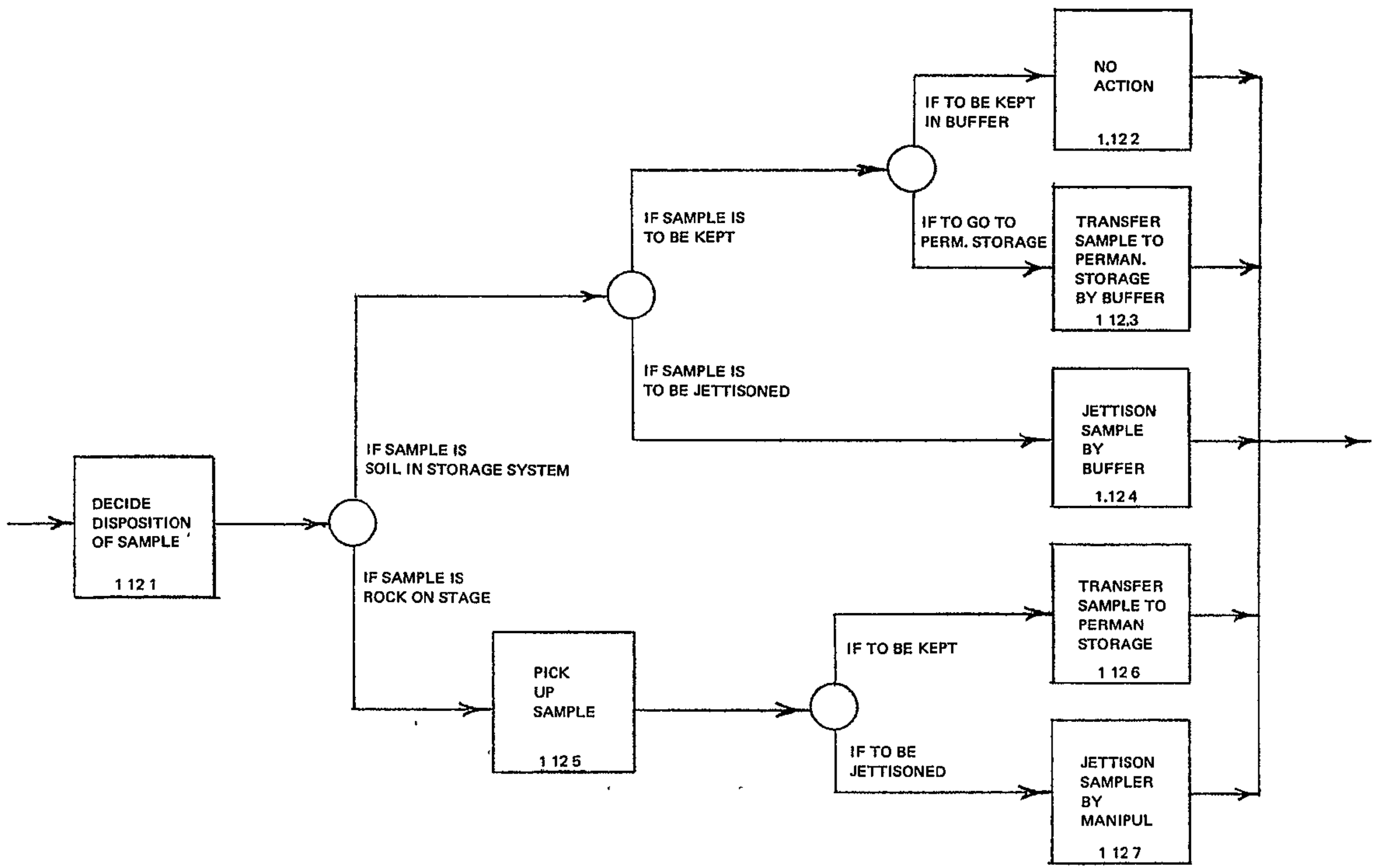

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Fig. 24. Major Sequence 1. 12 Sample Disposition

SAMPLE DISPOSITION OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.12.1 DECIDE DISPOSITION OF SAMPLE	Comparison of properties of subject sample vs lunar Ops Plan and prior samples to determine rejection or retention/analysis						
1.12.2 NO ACTION							
1.12 3 TRANSFER SAMPLE TO PERMANENT STORAGE BY BUFFER	Internal transfer of sample by buffer storage element						
1.12.4 JETTISON SAMPLE BY BUFFER	Rejection of sample by buffer storage element	←		SEE BELOW			→
1.12.4 1 ASSIGN TV MONITORING TO BUFFER	Provide TV coverage of buffer jettisonning	←		REF 1 8.2			→
1.12.4.2 PERFORM BUFFER JETTISON	Buffer jettisons sample	Buffer status TM	TM conversion	Buffer status	Monitor jettisonning	None	
1.12.4.3 STOP TV MONITORING	Turn off TV and replace lens cover	←		REF 1.8 8.2			→
1 12 5 PICK UP SAMPLE	Retrieve sample from viewing stage	←		SEE BELOW		→	Assumes presence of rock sample on viewing stage
1.12.5.1 START TV MONITORING	Initiate photo coverage	←	REF (NEW 1.8.2.1, OLD 1 8.1.1)			→	
1 12.5.2 CLEAR SAMPLE CAMERA	Lower viewing stage - to clear	Sample camera position	None	Sample camera position	Issue command Monitor execution	Command	Single step lunar operation
1 12.5.3 INSTALL TONGS	Mount tongs as tool on manipulator	←	REF (NEW 1.8.2, OLD 1.8.4)			→	

SAMPLE DISPOSITION (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH) SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 12.5.4 DEPLOY TONGS TO VIEWING STAGE Refer to sample acquisition	Move manipulator to viewing stage	Manipulator drive coordinates TV/TM data	Manipulator motion control TV/TM conversion	Manipulator position coordinates TV picture of tongs	Monitor deployment	Manipulator motion control commands	
1.12.5 5 SEIZE SAMPLE	Grasp rock sample with tongs	Manipulator drive coordinates TV/TM data	Manipulator motion control TV/TM conversion	Manipulator position coordinates TV picture	Issue discrete changes to be accomplished by manipulator	Manipulator motion control commands	
1 12 6 TRANSFER SAMPLE TO PERMANENT STORAGE	Store sample in bin storage	←		SEE BELOW			→
1.12 6 1 DEPLOY TONGS TO BIN STORAGE	Transport sample to ultimate storage location	←		REF 1 12.5.4			→
1 12 6 2 RELEASE TONGS GRASP	Open tongs to disengage	Tongs extension data TV/TM data	Tongs extension data conversion TV/TM conversion	Tongs extension position TV pictures	• Issue command • Monitor execution	Command	Single-command
1 12 6 3 STORE MANIPULATOR	Return manipulator to storage			REF 1 12 5.4			
1.12.6.4 STOP TV MONITORING	Turn off TV	TV/TM data	TV/TM conversion	TV pictures	Monitor extinction	Command	
1 12 7 JETTISON SAMPLE BY MANIPULATOR	Reject sample	←		SEE BELOW			→
1 12.7 1 SWING TONGS CLEAR OF VEHICLE	Transport sample to outside vehicle envelope	←		REF 1 12 5 4			→
1.12.7.2 RELEASE TONGS GRASP	Open tongs to disengage	←		REF 1, 12.6.2			→
1 12 7 3 STORE MANIPULATOR	Return manipulator to storage	←		REF 1.12 5 4			→
1 12 7 4 STOP TV MONITORING	Turn off TV	←		REF 1.12 6 4			→

N. MINERAL PHASE ANALYSIS (1.13)

1. Objective

The objectives of this sequence are to:

(1) Determination of identity and abundance of mineral present in the lunar regolith through use of X-ray diffractometry techniques.

(2) Determine spatial distribution of minerals over the lunar surface.

2. Scope

It includes:

(1) Sample preparation by pulverization device.

(2) Use of X-ray diffractometer to obtain diffractogram of sample material.

3. Assumption

(1) Sample to be analyzed is available in buffer storage.

(2) Material is of size, etc., to be processed by sample preparation device.

4. Discussion

This operation (Fig. 25) includes sample preparation, X-ray diffractometry, preparation of diffractogram, and analysis of accumulated data. Only sample preparations and the X-ray diffraction operations will be accomplished in real-time. The diffractogram and analysis operations will be accomplished in non-real time as convenient.

The preparation sequence involves obtaining a portion of the sample, pulverization, and insertion of the resulting sample powder into the diffractometer. Diffractions will include initialization of the device and scanning at appropriate scan rates.

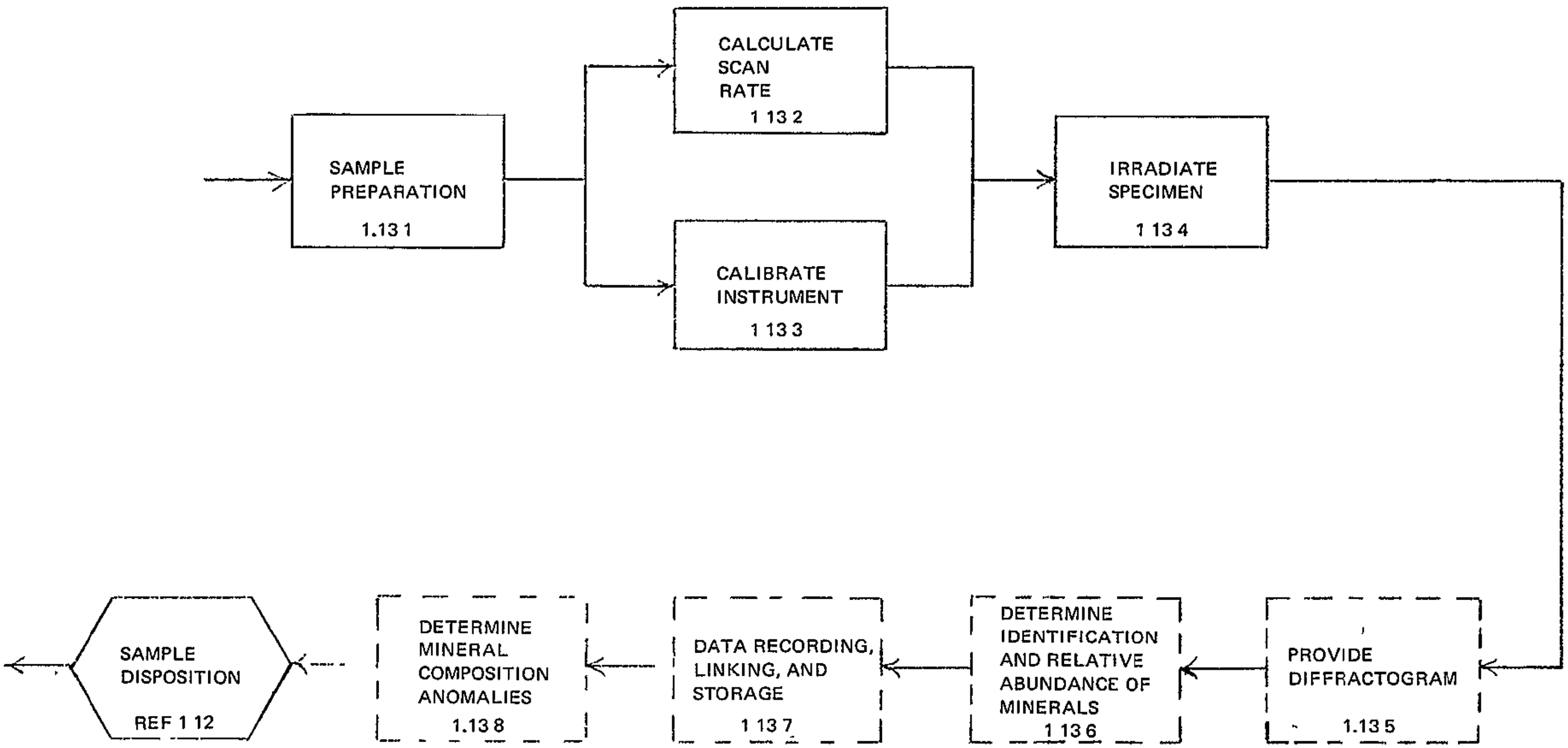

Fig. 25. Major Sequence 1.13 Mineral Phase Analysis

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1.13 MINERAL PHASE ANALYSIS (X-RAY DIFFRACTOMETER) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH) SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.13.1 SAMPLE PREPARATION	Determine whether sample is to be chipped and pulverized or just pulverized & generate the commands to point foreground camera during preparation, packaging and testing of sample	Video data depicting the position of the sample as it is cycled from prep site to test site	Processing video for display Video enhancement computer program	Foreground camera display of sample in various phases of preparation Video hard copy	Monitor sample specimen during preparation of sample and packaging	• Sample select command • Foreground camera pointing commands • Preparation commands 1) Clean 2) Chip 3) Pulverize • Command to package sample • Command to eject remains of sample and clean prep area	Rocks may be chipped prior to pulverizing and packaging Cores taken where rock is too big to lift
1.13.2 CALCULATE SCAN RATE	Determine initial scan rate in order to obtain optimum data	Digital data of scanning angle	Convert digital data to analog in proper engineering units	Scan rate display and alpha-numeric print out	Determine initial scan rate desired	Turn-on command for diffractometer Head positioning scan rate commands Sample advance command	Commands
1.13.3 CALIBRATE INSTRUMENT	Generate commands to calibrate instrument using standard sample Generate commands to move standard out of test area	Digital data containing standard sample output	Computer program to convert digital data into engineering units	Diffractogram of standard sample	Select standard or sample Adjust diffractometer for proper display Assess diffractograms and determine whether x-ray diffractometer is still calibrated	Diffractometer calibrate command Command standard to be stored	

MINERAL PHASE ANALYSIS (X-RAY DIFFRACTOMETER) (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1 13 4 IRRADIATE SPECIMEN	Generate necessary commands to position sample in test area	Video data from foreground camera	Processing video for display as in 1 8 1	Foreground camera display	Decision to move standard out and move sample into test area	Command sample to be placed in test area Command x-ray to irradiate sample	
1 13.5 PROVIDE DIFFRACTOGRAMS	Assess diffractograms	Digital data identifying types and relative abundance of mineral phases present in sample	Digital data processed for analysis Statistical accumulation and analysis of diffraction data-computer program	Diffractograms Digital displays	Analyze diffractograms and make corrections as required		
1.13.6 DETERMINE IDENTITY AND RELATIVE ABUNDANCE OF MINERALS	Identify relative abundance of minerals in sample from diffractometer	Diffractogram of 1.13.5	None	Mineral type vs % abundance Tabulated print out data	Analyse diffractogram data and provide subject tabulation	None	
1 13 7 DATA RECORDING, LINKING, AND STORAGE	Generate tabulated data of mineral abundance vs selenographic position	Tabulation of 1 13 6	Logging, recording and storing of data • Determine trends in mineral composition	Profile display showing mineral abundance vs selenographic position	Analyse traverse profile data		
1 13 8 DETERMINE MINERAL COMPOSITION ANOMALIES AND TABULATE	Generate mineral composition anomalies and tabulate for study	Diffractograms and associated tabulations both current and previous	Computer program • Group mineral composition anomalies	Tabulated print out of mineral composition anomalies	Analyse tabulated data		(1.6.10)

O. CHEMICAL ELEMENT ANALYSIS (1. 14)

1. Objective

The objectives of this sequence are to:

(1) Determine the identity and abundance of elements presented in lunar regolith through X-ray spectroscopic techniques.

(2) Determine spatial distribution.

2. Scope

It includes:

(1) Sample preparation by pulverization device.

(2) Use of X-ray spectrometer to obtain spectrogram of sample material.

3. Assumption

There are none for this sequence.

4. Discussion

This operation (Fig. 26) is identical to sequence 1. 13 (Fig. 25) except for use of an X-ray spectrometer in place of the X-ray diffractometer.

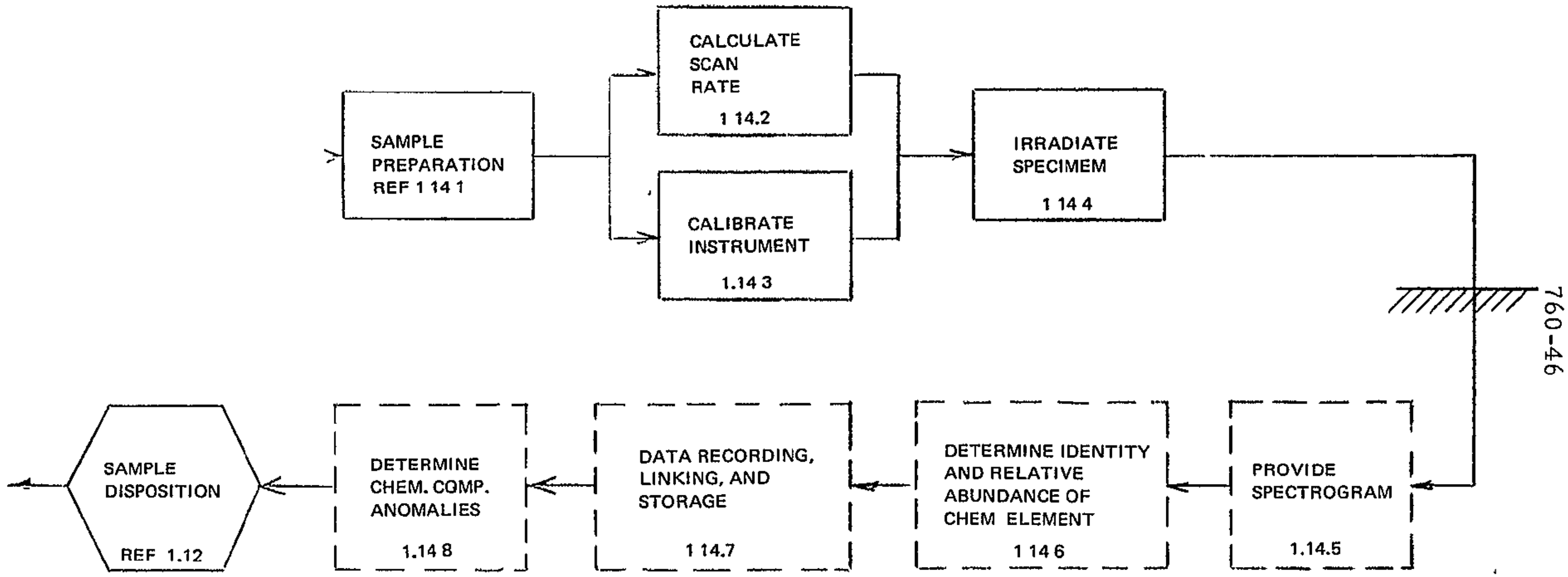

Fig. 26. Major Sequence 1. 14 Chemical Element Analysis

1.14 CHEMICAL ELEMENT ANALYSIS (X-RAY SPECTROMETER) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.14 1 SAMPLE PREPARATION	Determine whether sample is to be chipped and pulverized or just pulverized and generate commands to point foreground camera during preparation, packaging and testing of sample	Video data depicting the positioning of the sample as it is cycled from prep site to test site	Processing video for display Video enhancement computer program	Foreground camera display of sample in various phases of preparation Video hard copy	Monitor sample specimen during preparation of sample	Fortran camera pointing commands Sample select commands Sample prep commands 1) Clean 2) Chip 3) Pulverize Package portion of sample standby command preparation area clean command	Rocks may be cleaned, chipped and pulverized prior to packaging Cores taken from large rock may also be chipped and pulverized prior to packaging
1.14.2 CALCULATE SCAN RATE	Determine initial scan rate in order to obtain optimum data	Digital data depicting scanning angle	Convert digital data to analog data in proper engineering units	Scan rate alpha numeric print out	Select initial scan rate for sample	Spectometer turn-on command Head positioning command Sample advance command	
1.14.3 CALIBRATE INSTRUMENT	Generate commands to calibrate instrument using standard sample Generate command to move standard out and sample into test site verify spectrogram data for standard is valid	Digital data containing standard sample output	Computer program to convert digital data to engineering units	Spectogram of standard sample	Select standard or sample Adjust spectrogram for proper display Assess spectrogram and confirm whether x-ray spectrometer on LRV is calibrated	Spectrometer calibrate command Command standard to be stored Command x-ray spectrometer to irradiate standard	

CHEMICAL ELEMENT ANALYSIS (X-RAY SPECTROMETER) (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
1.14.4 IRRADIATE SPECIMEN	Generate necessary commands to scan sample in λ and obtain statistical λ and intensity information on secondary emission Generate commands to position sample in test area	Video data from foreground camera	Processing video for display as in 1.9.1	Foreground camera display	Decision to move standard out and move sample into test area	Command standard to move out and sample to move into test area Command x-ray to irradiate sample	
1 14.5 PROVIDE SPECTROGRAMS	Assess spectrograms	Digital data identifying the elemental composition of particulate specimen	Process data for analysis Statistical accumulation and an	Spectrograms and digital displays	Analyse spectrograms and make corrections as required		
1.14 6 DETERMINE IDENTITY AND RELATIVE ABUNDANCE OF ELEMENTS IN SPECIMEN	Identify relative abundance of elements in sample	Spectograms of 1.14.5	Logging, recording, and storing of data	Element type and abundance Tabulated printout	Analyse tabulated data from computer		
1.14.7 DATA RECORDING, LINKING, AND STORAGE	Generate tabulated data of element abundance vs selenographic position	Tabulations of 1.14.6	(1 14 6) • Determine trends in element composition	Profile display showing element abundance vs selenographic position	Analyse traverse profile and decide whether data is valid		
1.14.8 DETERMINE ELEMENTAL COMPOSITION ANOMALIES AND TABULATE	Generate element composition anomalies and tabulate for study	Spectograms and associated tabulations both current and previous	Computer program • Group element composition anomalies	Tabulated print out of element composition anomalies	Analyse tabulated data		(1 6.10)

P. MAJOR DIAGNOSTIC CHECKOUT (3.0)

1. Objectives.

The objectives of this sequence are to provide in-depth diagnostic checkout of the vehicle:

(1) At start of Automated Exploration Phase.
(2) Subsequent to major stressing of the vehicle.
(3) When significant anomalies are suspected.

2. Scope.

It includes:

(1) Provision of all vehicular systems with in-depth capability for functional checkout.
(2) Options for all provided degrees of checkout.
(3) Coverage of the restricted set of conditions pertinent to those encountered. It is anticipated that usage of this mode will not cover the complete spectrum of all possible conditions.
(4) Denying the exercising of irreversible functions.

3. Assumption

It is assumed that either the automated exploration phase has just been initiated, lunar night/day is about to begin, or the vehicle has been subjected to stress from a hazard or other phenomena.

4. Discussion

The Diagnostic Checkout (Fig. 27) of the LRV (and its instruments) consists of measuring selected quantities on board the vehicle, with or without exercising commandable stimuli, and interpreting the results as calibration of transform-type instruments or of the conditions which exist at the vehicle. The optimal extent of routine (continuous) condition testing does not encompass all possible measurements or all possible states of the vehicle. The major checkout mode complements routine checking by providing the capability for conducting any selected calibrations and measurements-of-state of which the vehicle is capable.

In general, the result of checkout is expected to be an improvement in knowledge of the condition (including calibration) of the vehicle and its instruments which will enable modification of the Lunar Operations Plan, as required, to remedy a flaw or prevent further failure.

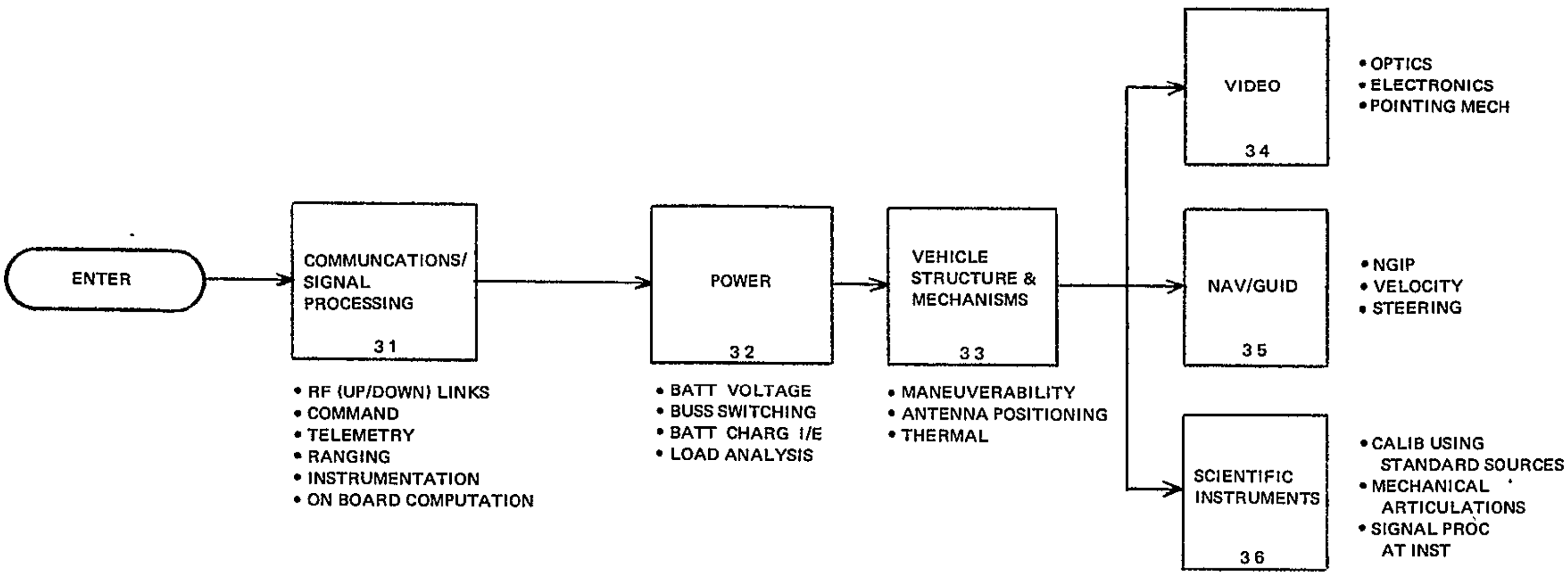

Fig. 27. 3.0 Major Diagnostic Checkout

PERIODIC MAJOR CHECKOUT OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
3 1 COMMUNICATIONS/ SIGNAL PROCESSING	• Operations on the Earth based equipment for communications/ signal processing tests • Analysis of communications signal processing for proper operation	Measurement of LRV • RF power out • Receiver gain • RF spectrum • Range	• TM data for display • Trend and limit analysis	• LRV TM data	• Analyze data for proper LRV status • Perform up/ downlink tests on LRV at DSIF	• Uplink commands for test sequence • Directions to DSN for test sequence of Earth based environment used for communications signal processing	Tests • RF power out • RF switching • Receiver gain • Spectrum • Ranging • Subcarrier frequency • Commutator switch • FM/PM mod characteristics
3 2 POWER	Analysis of power subsystem for proper operation	• LRV power data	• TM data for display • Trend and limit analysis	• LRV TM data	• Analyze data for proper LRV status and load analysis • Select load profile for analysis	Uplink commands for test sequence	Tests • Battery voltage • Bus switching • Battery charging current and voltage • Load analysis
3 3 VEHICLE MECHANISMS	Analysis of vehicle mechanisms for proper operation	• LRV mechanisms data • TV video	• TM data for display • Trend and limit analysis	• LRV TM data • Video display	• Analyze data for proper LRV mechanical operation • Execute mechanism manipulation activity	Uplink commands for test sequence	Tests • Locomotion • Steering load • Velocity load • Step load • Odometer calibration

PERIODIC MAJOR CHECKOUT (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
3 4 VIDEO	Analysis of vehicle video subsystems for proper operation	• TV camera data • TV video	• TM data for display • Trend and limit analysis • TV video for display	• LRV TM data • Video display	• Analyze camera data for proper camera response to commands • Analyze video for proper operation • Execute video test activity	Uplink commands for test sequence	Tests • Sync amplitude • White/black levels • Line frequency • Focus, filter, exposure commands • Grey scales • Resolution
3 5 NAVIGATION/ GUIDANCE	Analysis of navigation/guidance subsystems for proper operation	• DLRV TM data • NGIP data		• LRV TM data • Video display	• Execute navigation/ guidance test activity • Analyze TM data for proper operation	Uplink commands for test sequence	• Gyro drift rate • NGIP tests • Hazard detection tests

3 6 SCIENTIFIC INSTRUMENTS	Analysis of scientific instruments to ascertain proper performance	• LRV TM
		• Scientific instrument TM
			• TM data for display
			• Trends and limit analysis
			• Operate on calib and test data
				• Display received data
				• Display results of operations upon input data, i e
				  • DIFF calibration
				  • NGRA calibration
					• Execute test activity
					• Analyse data for proper operation of instruments
						• Uplink commands for test sequence	Tests
							• LASER scanner
							• NGRA
							• Gravimeter
							• Magnetometer
							• X-ray diff.
							• X-ray spect
							• Sample prep and storage
							• Retro reflect
							• Mass spect
							• Geophone
							• RGM

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Q. NAVIGATION UPDATE (4.0)

1. Objective

The objective of this sequence is to reduce the uncertainty from that level which is tolerable in dead reckoning to that which is required by science.

2. Scope.

It includes:

(1) Precision determination of vehicle position and heading by means of four potential methods:

(a) Landmark recognition

(b) Celestial navigation

(c) RF tracking

(d) Laser ranging

(2) Science on a non-interference basis.

(3) Housekeeping functions.

3. Assumption

There are no assumptions made for this mode.

4. Discussion

The Day Navigation Update Mode (Fig. 28) provides a means to reduce the accumulated error arising from the dead reckoning computation of the Traverse Mode. It provides an update on the vehicle position and heading using direct measurements. Four methods of navigational updating are included in the operations: 1) landmark recognition (Fig. 29), 2) celestial navigation (Fig. 32), 3) RF tracking (Fig. 33), and 4) earth-based laser ranging. Celestial navigation and RF tracking are considered back-up methods to landmark recognition since they are time consuming and have limited accuracy. Laser ranging is limited to certain periods of the day during station visibility and hence can not always be used. The primary method to be relied upon will that of landmark recognition.

The basic principle of landmark navigation is to obtain precise angular measurements to identified landmarks using a high resolution TV camera (Fig. 30). The data can then be correlated with reference map to determine a precise vehicle position and heading (Fig. 31). The method described in this report requires that four landmarks be visible from one vehicle location. This provides sufficient information in itself to determine the position plus provide a degree of confidence on the measurement. If less than four, but more than two landmarks are visible, the vehicle will be moved after obtaining the initial data to a second location. This second location will be a measured distance from the first, and new angular measurements on the same two landmarks will be taken. This again provides sufficient data plus a validity check. A degraded mode is conceivable using one landmark and sun-angle information, but it is not included here because it does not provide the validity check.

The celestial navigation method (Fig. 32) requires obtaining four hi-resolution TV pictures. From these pictures and a knowledge of the lunar emphemeris, the astronomical coordinates of the local zenith can be computed and the resulting vehicle position and heading determined. This method requires that the vehicle be stationary for approximately twenty-four minutes to allow for the processing of the required four TV pictures and an additional thirty minutes to process the TV data to determine vehicle position and heading during which time the vehicle may be in motion.

The RF tracking method (Fig. 33) requires the availability of earth-tracking stations, a second lunar tracking source, and the vehicle must remain stationary for a period of several hours to obtain sufficient RF doppler data.

The last ranging method is discussed in the Science Mode.

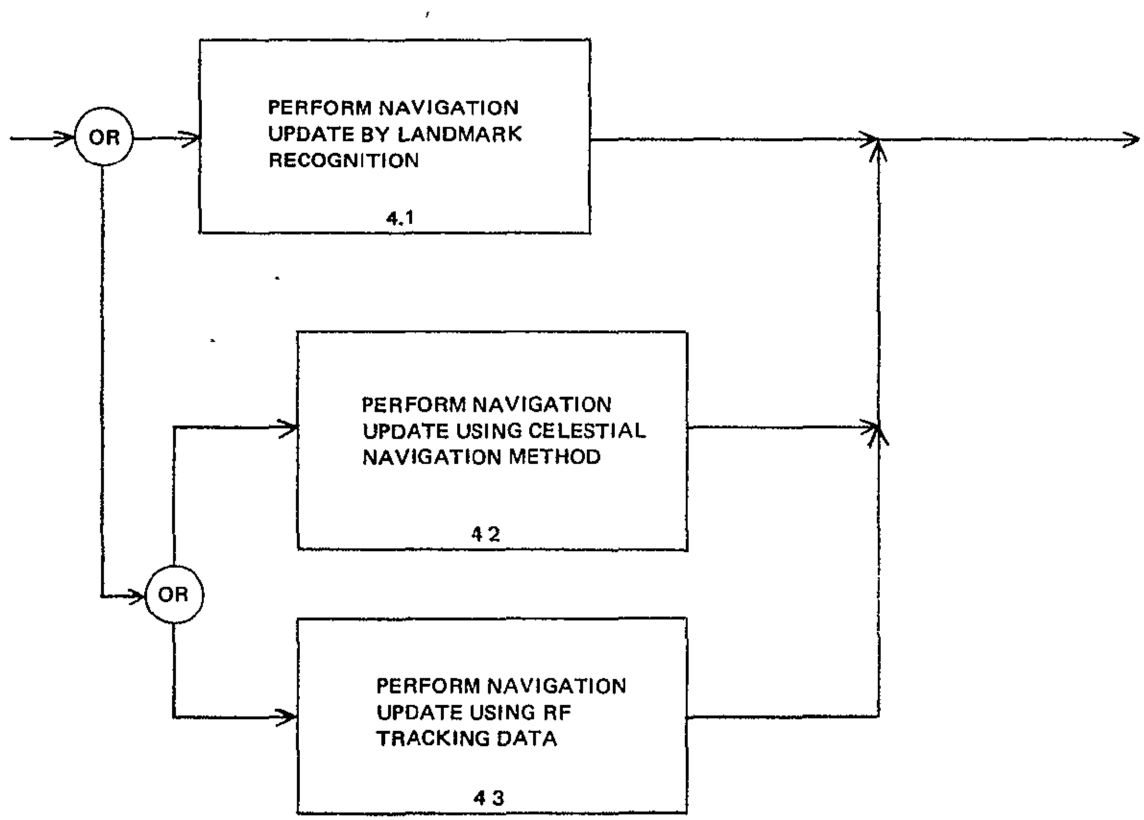

Fig. 28. 4.0 Navigation/Guidance Stop Mode Compilation of Major Sequences

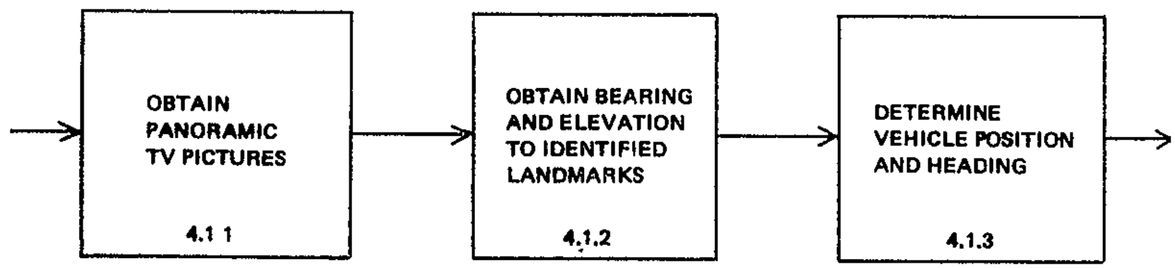

Fig. 29. 4.1 Perform Navigation Update by Landmark Recognition - Minor Sequences

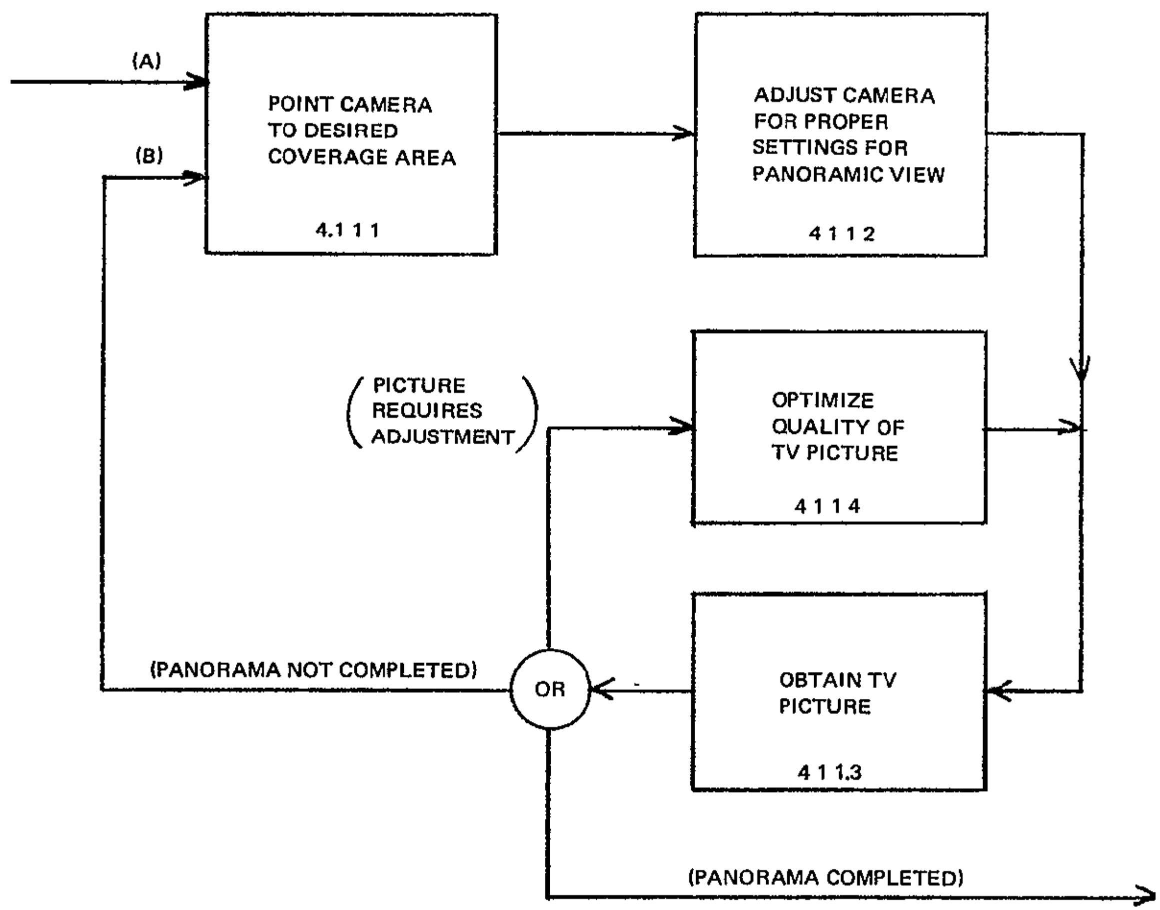

Fig. 30. 4. 1. 1 Obtain Panoramic TV Pictures - Mission Functions

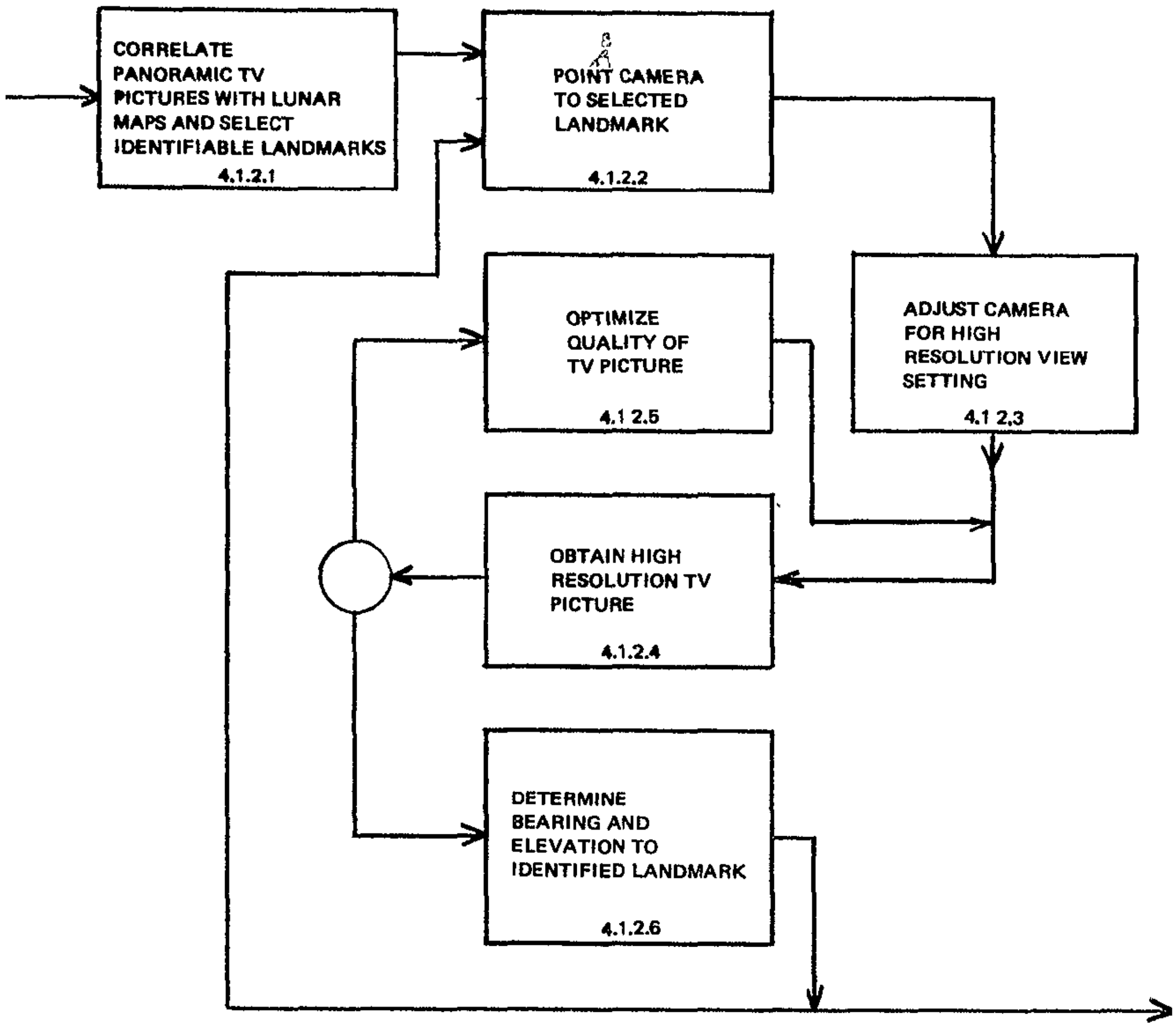

Fig. 31. 4.1.2 Obtain Bearing and Elevation to Identified Landmarks - Mission Functions

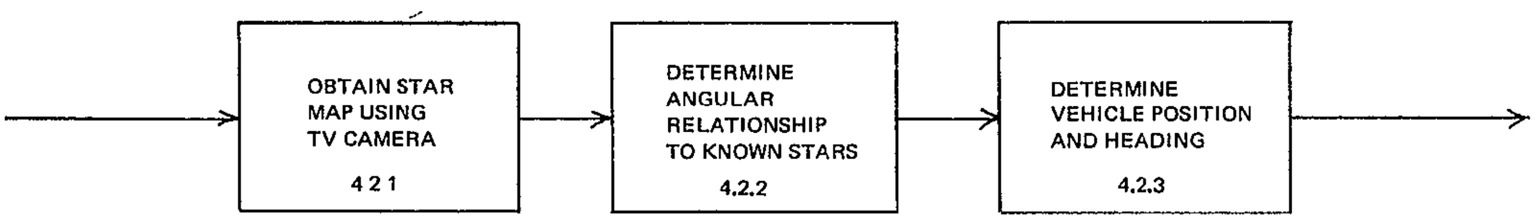

Fig. 32. 4. 2 Perform Navigation Update Using Celestial Navigation Method - Minor Sequences

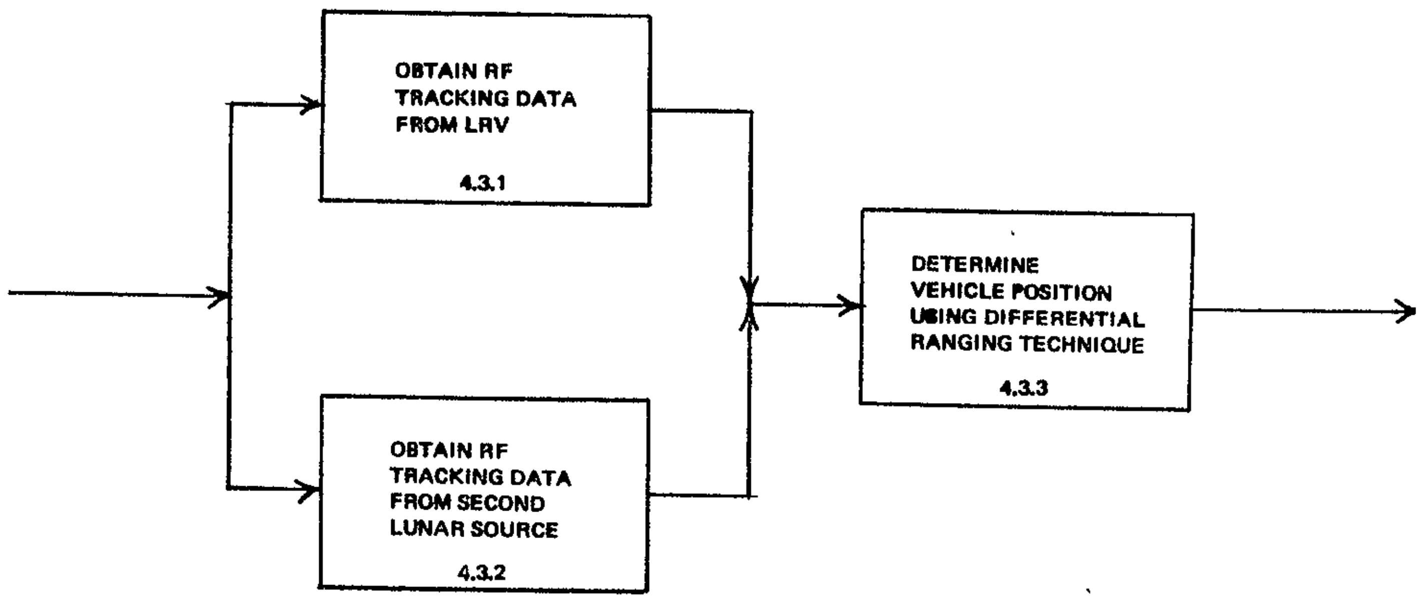

Fig. 33. 4.3 Perform Navigation Update Using RF Tracking Data

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4.1 PERFORM NAVIGATION UPDATE BY LANDMARK RECOGNITION OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
4.1.1 OBTAIN PANORAMIC TV PICTURES 4.1.1.1 POINT CAMERA TO DESIRED COVERAGE AREA ENTRY "A"	Determine TV positioning commands from pointing angles for complete panorama based on LRV orientation and generate the necessary commands to point camera in desired starting orientation	1) Vehicle attitude 2) TV coordinate system—vehicle coordinate system relationship 3) Vehicle position (via dead reckoning) 4) Vehicle heading (via dead reckoning) 5) Latest TV pictures 6) Latest TV pointing angles 7) Sun line 8) Desired starting orientation	Convert lunar reference angles of desired direction biased by vehicle attitude into TV pointing angles and corresponding TV position commands	Video display of last received TV picture Presentation of vehicle attitude, TV pointing angles, and corresponding TV commands for complete panorama	Assess TV pointing angles to determine attainability of acceptable panorama (i e , within mechanical limits of TV positioning control) not affected by Sun line	Pointing angle commands to LRV to position TV camera for desired orientation	MOC function 6 0B
ENTRY "B"	Generate necessary commands to point camera to next desired azimuthal sweep direction	1) Latest TV picture 2) Same as 4.1.1.1.4	Sequential pointing angles to obtain panoramic views	Same as 4.1.1.1 A	Verify via video that the panorama coverage is proper	Pointing angle commands to LRV to position TV camera for desired subsequent direction	

4 1 PERFORM NAVIGATION UPDATE BY LANDMARK RECOGNITION (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
4 1 1. 2 ADJUST CAMERA FOR PROPER SETTINGS FOR PANORAMIC VIEW	Generate the necessary commands to set focal length and iris setting for panoramic pictures	1) Present TV focus 2) Present TV brightness 3) Latest TV picture if applicable 4) Sun line	Compute focal length and iris settings for camera based on distance and light conditions	Focal length and iris setting commands vs TV azimuthal position (these commands to be automatically sequenced with TV position commands)	Assess displayed commands to verify that they are proper for given conditions	Focal length and iris setting adjustment commands to LRV for desired starting orientation	MOC function 6. 0A
4 1. 1. 3 OBTAIN TV PICTURE	Generate "take frame" command to obtain TV picture and process received picture	1) "LRV ready" for panorama as verified by TM 2) TV picture	Store TV picture in retrievable storage device	Standard	Verify readiness of LRV for picture taking	1) "Take frame" command to LRV 2) Hard copy of TV picture	MOC function 6 0B
Exit from 4 1 1 3 to 4 1 1 4	If TV picture requires adjustment						
to 4 1 1 1 B	If panorama is not completed						
to exit 4 1 1	If panorama is completed						
4 1 1 4 OPTIMIZE QUALITY OF TV PICTURE	Assess TV picture to determine if picture can be improved by command adjustment	1) TV picture 2) TV engineering data	Standard	Standard	Provide assessment of TV picture	TV engineering adjustment command	MOC function 6 0A

4 1 PERFORM NAVIGATION UPDATE BY LANDMARK RECOGNITION (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
4 1 2 OBTAIN BEARING AND ELEVATION TO IDENTIFIED LANDMARKS							
4 1 2 1 CORRELATE PANORAMIC TV PICTURES WITH LUNAR MARS AND SELECT IDENTIFIABLE LANDMARKS (can be initiated concurrently with panoramic process but may require additional time (DT) to complete orientation recognition)	Fit LRV position to lunar map using dead reckoning data and panoramic TV pictures Select distinguishable landmarks for high resolution TV pictures	1) Dead reckoning position and heading data 2) Lunar reference maps 3) Panoramic TV pictures identified in field of view by TV coordinates 4) Present TV pointing angles		Video presentation of panoramic TV pictures related to vehicle heading by means of superimposed arrow or line	1) Select landmarks visible in panorama for obtaining high resolution pictures 2) Determine bearings and elevations to selected landmarks vis correlation of TV pictures to lunar maps (TV coordinates)	General bearings and elevation to selected landmarks in TV coordinates (to 4 1 1 2)	MOC function 1 0A, B
4 1 2 2 POINT CAMERA TO SELECTED LANDMARK ENTRY "A"	Generate pointing angle commands to aim camera at selected landmark	1) General bearings and elevation to selected landmarks in TV coordinates 2) Present TV pointing angles	Determine TV pointing commands for high resolution picture of selected landmark	Same as 4 1 2 1 but includes camera orientation	Verify via TM that the camera is positioned as desired	Pointing angle commands to camera mount	MOC function 6 0B
4 1 2 3 ADJUST CAMERA FOR HIGH RESOLUTION VIEW SETTING ENTRY "B"	Same but sequences to next landmark generate the necessary commands to set the focal length and iris setting for a high resolution picture	1) TV focus 2) TV brightness 3) Last TV picture		Same as 4 1 2 1	Determine focal length and iris setting for camera based on distance and light conditions	Focal length and iris setting adjustment commands to vehicle	MOC function 6 0B

4 1 PERFORM NAVIGATION UPDATE BY LANDMARK RECOGNITION (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
4 1 2 4 OBTAIN HIGH RESOLUTION TV PICTURE (exit from 4 1 2 4 to 4 1 2 5 if picture requires command adjustment, otherwise exit to 4 1 2 6)	Generate "take frame" command to obtain picture and process received picture	1) TV picture 2) "Camera ready" inputs		Presentation of high resolution TV picture relative to panoramic view	Assess readiness of vehicle for picture taking	1) "Take frame" command to vehicle 2) Hard copy of TV picture	MOC function 6 0B
4 1 2 5 OPTIMIZE QUALITY OF TV PICTURE	Assessment of TV picture to determine if picture quality can be improved by command adjustment Generate necessary commands	1) TV brightness 2) Focus 3) TV pictures 4) TV engineering data		Same as 4 1 2 4	Provide the assessment of the TV picture	TV engineering adjustment commands	MOC function 6 0A
4 1 2 6 DETERMINE BEARING AND ELEVATION TO IDENTIFIED LANDMARK (exit from 4 1 2 6 to 4 1 2 2 if other landmarks available otherwise exit to end 4 1 2)	Photometric process to extract bearing and elevation data from identified landmark relative to local vertical and vehicle heading	1) High resolution TV pictures 2) Camera pointing angles 3) Vehicle attitude		Photocopy of selected landmark related to lunar topographic view	Topography specialist to correlate high resolution TV pictures with lunar map to obtain bearing and elevation data	Established bearings and elevations to known landmarks relative to local vertical and vehicle heading	MOC function 1 0A, B

OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
4 1 3 PERFORM NAVIGATION UPDATE BY LANDMARK RECOGNITION 4 1 3 DETERMINE VEHICLE POSITION AND HEADING	Update vehicle position and heading data using bearing and elevation data to identified landmarks	Bearing and elevation to known landmarks	Process data using triangulation methods or employ a statistical approach to combine data from dead reckoning	Same as 4 1 2 6	Control computation process to ensure that sufficient data are available to attain desired accuracy	Updated data on vehicle position and heading in selenographic coordinate system	
4 2 PERFORM NAVIGATION UPDATE USING CELESTIAL NAVIGATION METHOD 4 2 1 OBTAIN STAR MAP, USING TV CAMERA	Determine approximate direction of stars of interest in TV coordinates	1) Celestial coordinates of stars of interest 2) Lunar ephemeris 3) Vehicle attitude 4) Sun line 5) TV attitude	Transform celestial coordinates of stars of interest into corresponding TV coordinates Determine TV commands to obtain pictures of nominal resolution	Direction of stars and sun in TV coordinates TV commands	Verify freedom from interference with sun	Generate nominal resolution TV pointing and exposure commands to vehicle	
	Analyze nominal resolution star pictures and obtain high resolution TV pictures of stars of interest	TV pictures of nominal resolution	Identify stars in TV pictures Determine TV commands required for high resolution TV of stars of interest	Nominal resolution TV pictures of stars of interest TV commands for high resolution pictures of stars of interest	Same as above Selection of stars of interest	Generate high resolution and exposure commands to vehicle	
4 2 2 DETERMINE ANGULAR RELATIONSHIP TO KNOWN STARS	Determine direction of stars of interest in TV coordinates	TV pictures of high resolution	Detect position of stars in TV field	TV coordinates of stars of interest	Validate detected position of stars	TV coordinates of stars of interest	

OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
4 2 3 DETERMINE VEHICLE POSITION AND HEADING	Determine position and heading on lunar surface from TV pointing angles to known stars, vehicle attitude	1) Stellar ephemeris 2) Lunar ephemeris 3) TV coordinates of stars 4) Vehicle attitude 5) TV attitude	Transformation from pointing angles to vehicle position	Vehicle position and heading in selenographic coordinates	Verify that computer results are consistent with other data available	Vehicle position and heading in selenographic coordinates	
4 3 PERFORM NAVIGATION UPDATE USING RF TRACKING DATA 4 3 1 OBTAIN RF TRACKING DATA FROM LRV	Obtain sufficient RF doppler data from LRV via tracking station	1) RF doppler data from LRV 2) Ephemeris data	Extract doppler data from RF tracking signals from LRV		Ensure vehicle stationary for sufficient period of time to obtain valid RF doppler data	Doppler data from LRV to 4 3 3	
4 3 2 OBTAIN RF TRACKING DATA FROM SECONDARY LUNAR SOURCES	Obtain sufficient RF doppler data from such secondary lunar sources as RGM, LM, and ALSEP	1) RF doppler data from secondary lunar sources 2) Position data on location of secondary lunar sources	Extract doppler data from RF tracking signals from LRV		Ensure validity of RF data from secondary lunar sources	Doppler data from secondary lunar sources	
4 3 3 DETERMINE VEHICLE POSITION USING DIFFERENTIAL-RANGING TECHNIQUE	Process doppler data from LRV and secondary lunar sources to extract position data	1) Doppler data from LRV 2) Doppler data from secondary lunar sources 3) Ephemeris data	Process doppler data to calculate LRV position based on doppler shift		Provide an assessment of accuracy of computed position based on received RF data	LRV position update data in selenographic coordinates	

R. DAY TRAVERSE MODE SUMMARY (5.0).

1. Objective.

The objective of this mode is:

(1) To provide assured safe delivery of the LRV to its next assigned destination.

(2) To provide science operations required while en-route.

2. Scope.

This mode includes all "driving" or mobile operations, including stops initiated by the vehicle because of hazards and stops initiated by MOC to permit hazard evaluation. It terminates upon reaching its current "step" destination or upon the initiation of any other mode.

3. Assumption

(1) Decision made to proceed to next target.

(2) Next target has been identified.

(3) Operating restraints are known.

(4) Position and heading at start of traverse are known.

4. Discussion

The Day Traverse Mode (Fig. 34) permits mission management to move the vehicle from one location to another. It is the only mode which permits vehicle motion. The mode prepares the vehicle for motion and controls the motion of the vehicle. A driver/operator controls the start/stop and steering of the vehicle in real time. Using real time TV he avoids visible hazards by judicious steering control. He follows the planned course stopping at the prescribed location.

During the traverse, vehicle position and heading are continuously computed with respect to the last update point using dead reckoning techniques.

Hazards detected by the vehicle sensors are evaluated to determine their effect on vehicle mobility.

Mission management is advised as to the nature of hazards and their impact on attaining the target objective.

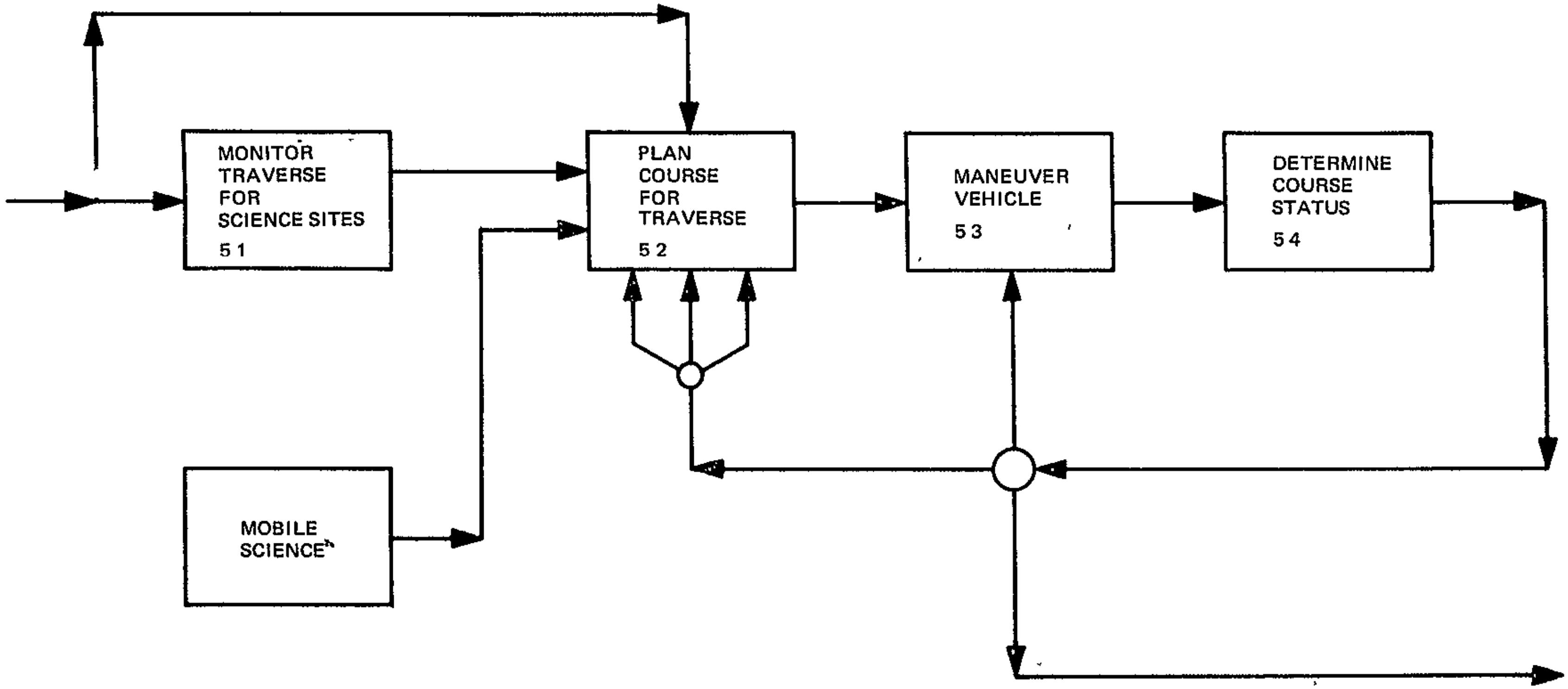


Fig. 34. 5.0 Traverse Mode Compilation of all Major Sequences

760-46

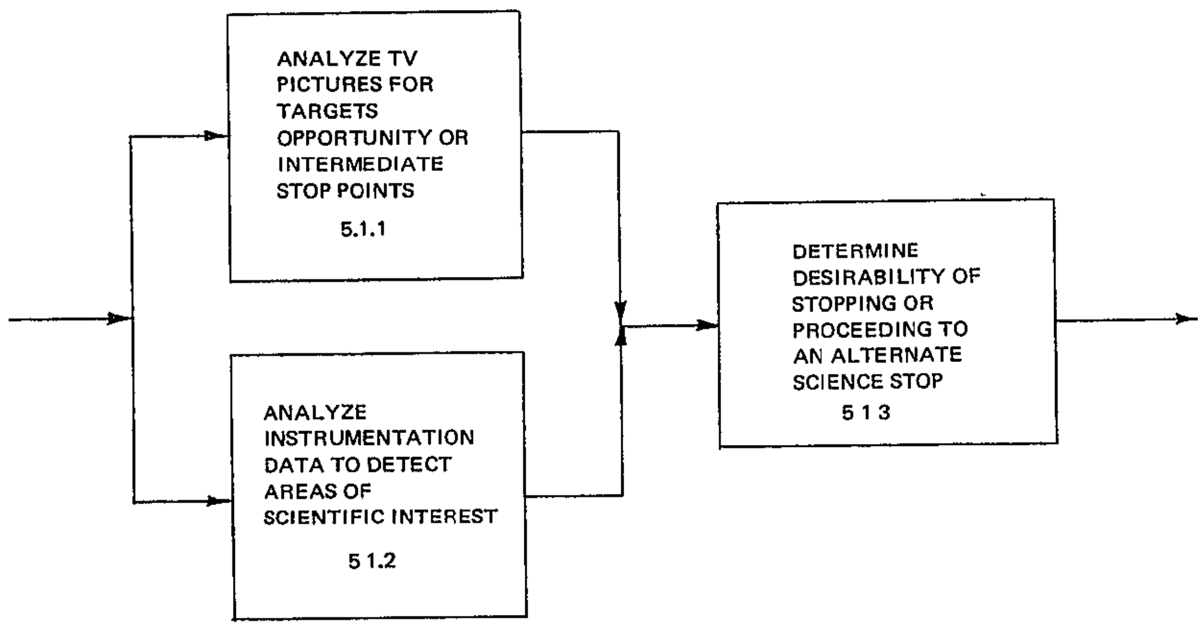


Fig. 35. Minor Sequence 5.1 Monitor Traverse for Science Sites

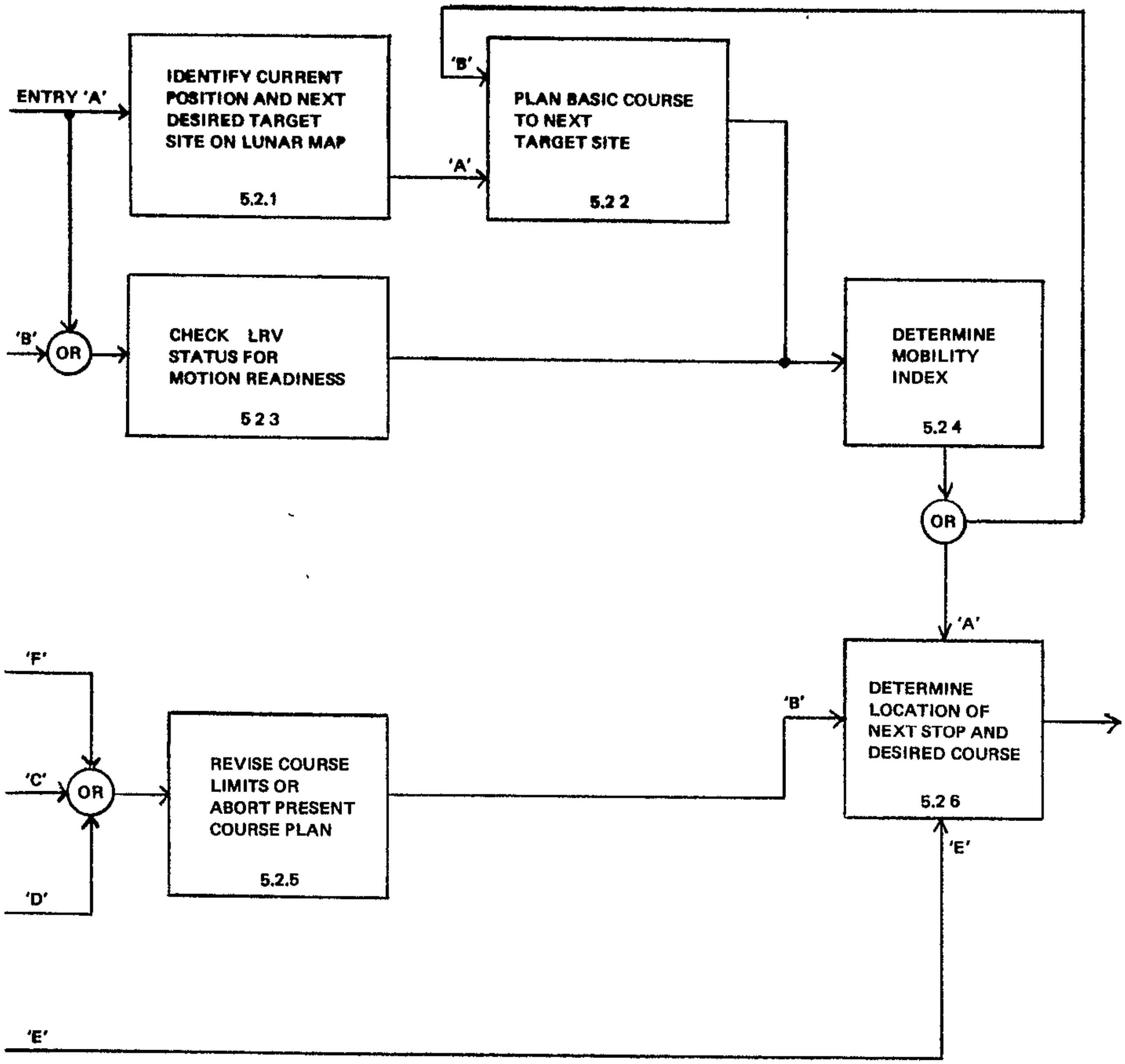


Fig. 36. Minor Sequence 5.2 Plan Course for Traverse

760-46

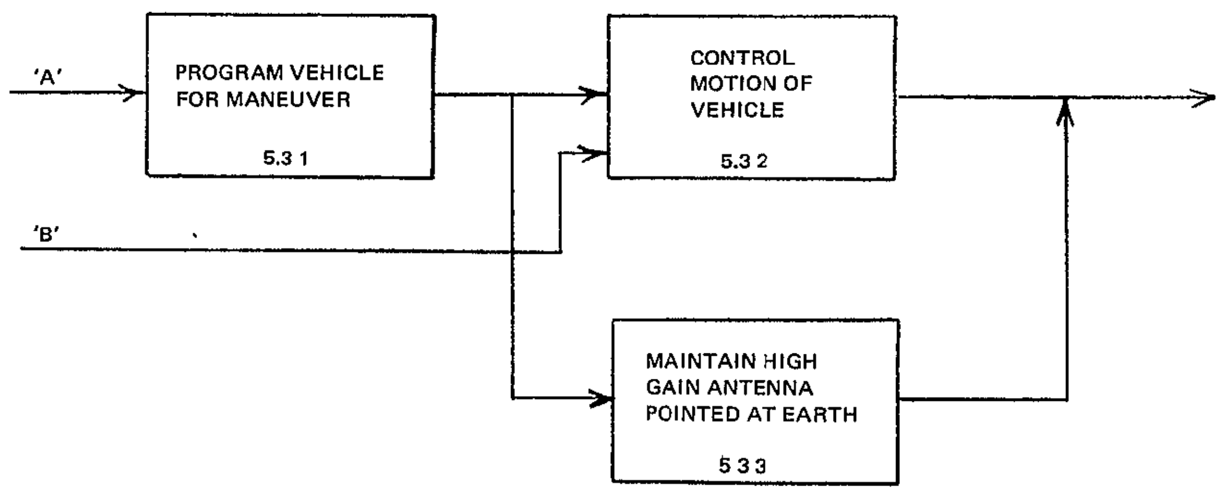


Fig. 37. Minor Sequence 5.3 Maneuver Vehicle

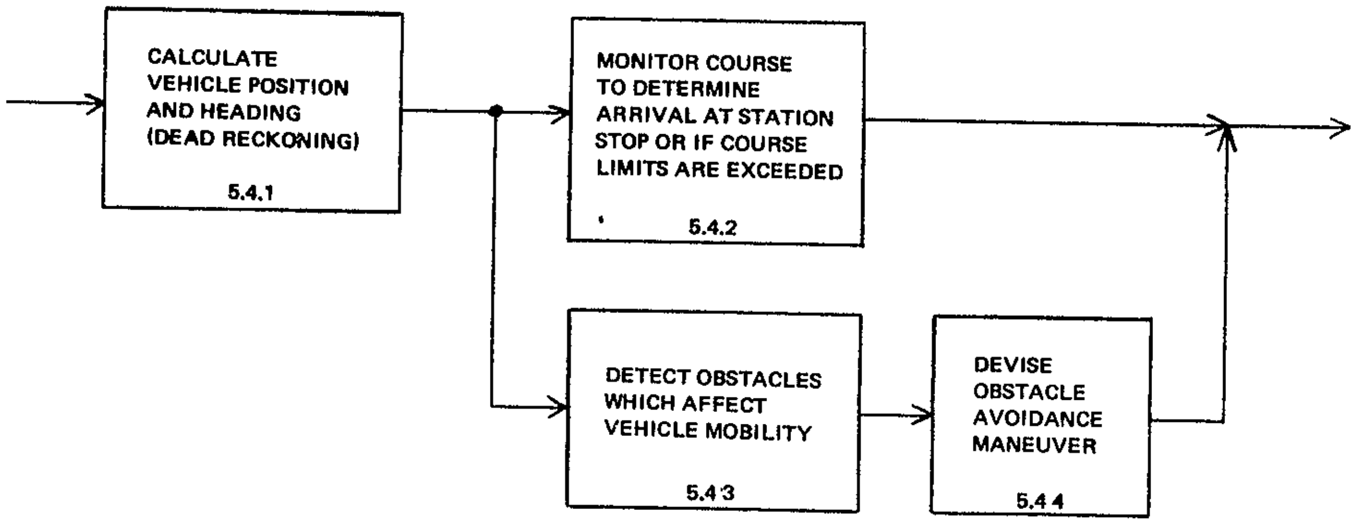


Fig. 38. Minor Sequence 5.4 Determine Track Status

TRAVERSE MODE OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5.1 MONITOR TRAVERSE FOR SCIENCE SITES	Analyze TV pictures, available science data to select targets of opportunities while en route to new target site	1) TV pictures 2) Processed data from tactile sensors and operational science equipment		Video display	Provide assessment of data to determine the desirability of stopping LRV	Decision to stop LRV	
5 2 PLAN COURSE FOR TRAVERSE 5 2 1 IDENTIFY CURRENT POSITION AND NEXT DESIRED TARGET STOP ON LUNAR MAP	Identify starting point from navigation update and the location of next target site on a lunar reference	1) Updated station fix data 2) Selected target site and schedule 3) Lunar reference map scaled in selenographic coordinates		1) Lunar map relating LRV current position and heading and selected target site (mockup, screen projection or overlay)	1) Provide identification of vehicle location and next target site	1) Identification of LRV position and heading and selected target site	MOC function NAV 4 0A
5 2 2 PLAN BASIC COURSE TO NEXT TARGET SITE (ENTRY "A")	Plot course to next target site giving consideration to lunar obstacles and capability of vehicle to negotiate anticipated obstacles, and the need to keep landmarks within view Revise basic course to accomodate constraints determined in 5 2 4	1) Identification of LRV position and selected target site 2) High resolution lunar map of immediate area 3) TV pictures of immediate area 4) Mobility index constraints	Use computer program of lunar surface model to exclude hazardous areas, optimize course for min time traversal	Same as 5 1 1 Same	Provide the assessment of the terrain to select a course to the desired target site that is within the mobility characteristics of the LRV Select revised course	1) Lunar map in selenographic coordinates displaying the desired course to the next target site Same	MOC function NAV 4 0A

TRAVERSE MODE (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH) SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5 2 3 CHECK LRV STATUS FOR MOTION READINESS (ENTRY "B")							
5 2.3.1 ASSESSMENT OF NAVIGATIONAL EQUIPMENT	Assess status of all navigational equipment Generate commands to improve performance when possible	1) TV engineering data 2) Navigation/ Guidance instrumentation data 3) Vehicle status data		Status display of navigational equipment	Assess performance of navigational equipment against performance standards. Ascertain if performance can be improved by command adjustmer s and generate commands.	1) Generate commands to peak the performance of navigational equipment 2) Determination of useability of navigation equipment	MOC function NAV 8.0, 9 0, 10 0
5 2.3.2 ASSESSMENT OF GUIDANCE EQUIPMENT	Assess status of all guidance equipment and readiness of vehicle for maneuver execution. Command select redundant equipment if necessary	1) Motion control engineering data 2) Vehicle status data 3) Payload status data		Status display of guidance equipment	Assess performance of guidance equipment against performance standards Make decision concerning use of redundant units if performance of prime equipment is questionable	1) Generate commands to select redundant units if necessary 2) Determination of useability of guidance equipment 3) Decision that vehicle is ready for maneuver	MOC function guid 6 0
5 2 3.3 ASSESSMENT OF SCIENCE EQUIPMENT	Assess status of science equipment to determine if equipment is ready for traverse mode, i e , stowed, locked, turned off etc.	1) Inputs from science activity in regard to status of each instrument and completion status of experiments		1) Display of all equipment status to relate operational readiness for traverse 2) Display relating status of experiments	Provide assessment of science equipment	Verification that science equipment is ready for traverse	

TRAVERSE MODE (contd)/ PLAN COURSE (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5.2 3 4 ASSESSMENT OF VEHICLE EQUIPMENT	Assess status of all vehicle equipment to determine if equipment is ready for transverse mode	Engineering TM data from each vehicle subsystem	Standard process-to extract useable data from engineering TM measurements	1) Display of each subsystem status to relate operational readiness for traverse	Provide assessment of each subsystem	Verification that vehicle is ready for traverse	
5.2 4 DETERMINE MOBILITY INDEX							
5 2 4 1 ASSESSMENT OF TRAVERSE TERRAIN	Assessment of terrain for next traverse to determent precautionary measures to take in controlling velocity of the vehicle	1) TV pictures 2) Landmark charts, and photos 3) Planned course	Use model of lunar terrain to aid in assessment	1) Video presentation of terrain 2) Planned course superimposed on lunar map 3) Predicted vehicle elevation changes along course (N-S and E-W presentation)	Provide the assessment of the terrain to determine the upper bound for vehicle speed	1) Maximum permitted speed	
5.2.4.2 ASSESSMENT OF STORED ENERGY CAPACITY	Determine stored energy capacity of vehicle and whether constraints shall be applied to vehicle speed or traverse distance	1) Engineering data 2) Predicted on/off times of all loads	Use model of LRV power system to evaluate effects of loads during traverse		Compute the energy (watt-hours) presently available and the anticipated energy dissipation for the course Determine distance and time constraints to operate within design limits of LRV.	1) Maximum distance 2) Speed constraints 3) Predicted power profile for selected course	

TRAVERSE MODE (contd)/ PLAN COURSE (contd)	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5 2 4 3 ASSESSMENT OF VEHICLE THERMAL CONDITIONS	Assessment of vehicle thermal sensors and lunar thermal environment to determine any operational constraints due to thermal conditions or induced heating	1) Engineering data 2) Sun position throughout course 3) LRV locomotion drive design data 4) Predicted power profile	A thermal model of LRV shall be available to evaluate thermal conditions and effect on LRV mobility	Time extrapolation of thermal conditions (TM points) on LRV, based on present thermal conditions, predicted power profile, terrain of course, and sun line throughout course	Assess thermal profile to determine distance, time and speed constraints to operate within design limits of LRV	1) Maximum distance 2) Maximum time 3) Speed constraints 4) Predicted thermal profile	
5.2.4.4 ASSESSMENT OF SUN-ANGLES OF TERRAIN VISIBILITY	Assess sun line angle and effect on TV camera usable in regard to TV view angles constraints and obstacle detection capability	1) Present sun angles 2) Present time of day 3) Planned course 4) Predicted average speed		Video presentation of terrain relating sun line direction Plot sun line vs distance along course	Provide the assessment of sun line effect on TV usage	1) Speed constraints 2) Vehicle heading constraints	
5 2 4 5 MOBILITY CONTROL DETERMINATION	Determine the LRV speed options and the related max time or max distance constraints	1) Speed constraints 2) Max distance inputs 3) Max time inputs	A computer program to evaluate effects of speed on LRV performance		Provide a parametric relationship of speed vs time and distance constraints	1) Parametric presentation of speed options	
5 2.4 6 ASSESSMENT OF EARTH-ANGLES ON COMMUNICATION VISIBILITY	Assess area about selected course to determine if terrain may pose problems with communication link.	1) Lunar Maps 2) Planned course		A display relating LRV position and attitude to Earth ground stations for identified problem areas along planned course	Provide the assessment of terrain effect on communication link	1) Identification of selected areas to avoid along course	

TRAVERSE MODE (contd)/ PLAN COURSE (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5.2 5 REVISE COURSE LIMITS OR ABORT PRESENT COURSE PLAN (TIME TO REVISE COURSE LIMITS)	Evaluate inputs and determine the necessary action to take. Revise course limits to coincide with LRV path if acceptable Abort present course if target site is revised	1) Decision to proceed to an alternate or intermediate stop point 2) "Off course status exceeds acceptable limits" 3) "Planned target site not accessible by planned traverse" 4) Current TV pictures 5) Lunar maps of immediate area		Same as 5 2.1	Determine the course of action to take as a result of the need to revise current traverse	1) Abort present course plan 2) Course limits revision to coincide with vehicle path	MOC functions 4 0A and 5 0B
5 2 6 DETERMINE LOCATION OF NEXT STOP AND DESIRED COURSE ENTRY "A"	Evaluation of all inputs to select the next station stop Identify the route by specifying the heading and distance for each leg of the traverse Select an appropriate speed based on constraints	A1) Parametric presentation of speed options A2) Selected course A3) Selected target A4) Heading constraints		Same as 5 2 4.1	Provide the assessment to select the route and vehicle speed	A1) Vehicle heading A2) Step distance associated with each heading A3) Vehicle speed	MOC functions 4 0B

TRAVERSE MODE (contd)/ PLAN COURSE (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5 2 6 (contd) ENTRY "B"	Revise planned course to agree with actual traverse or revise stop point if target site not accessible or is revised	B1) Present position and heading data B2) "Abort present course plan" B3) Course limits revision		Same as 5 2 4 1 but with planned course corrected to agree with actual traverse	Command LRV to stop if target site not accessible or is revised	B1) "Stop LRV"	
ENTRY "E"	Derive maneuver commands to move LRV in accordance with science operations	E1) Identification of selected target or specific maneuvers to be accomplished		Video presentation of terrain	Derive the necessary maneuver commands to move the LRV	E1) Heading commands E2) Step distance commands	

TRAVERSE MODE (contd)/ MANEUVER VEHICLE OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5 3.1 PROGRAM VEHICLE FOR MANEUVER	Generate the necessary commands to initialize the vehicle's computer and guidance system for the next traverse	1) LRV computer data 2) LRV gyro data	A computer simulation of the vehicle control system may be desirable to aid in selecting the appropriate commands	1) Display of LRV computer and gyro TM outputs	Assess the current status of the computer and gyro and determine the necessary commands to provide the update for the next maneuver	1) Computer CMDS 2) Gyro control CMDS	MOC function NAV 8 0 & 10 0
5 3 2 CONTROL MOTION OF VEHICLE	Operator/driver controls motion of LRV through Joy stick operation. Controls stop/go, speed and heading Maintains selected course, avoiding obstacles, and stops at desired station stop	1) Selected heading 2) Selected speed 3) Step distance 4) TV pictures 5) Current position and heading data 6) Course status input	Same as 5 2 1 with the additional capability of evaluating Joy stick commands before permitting execution by vehicle	1) Vehicle movement displayed on a Lunar map 2) Video presentation of received TV pictures 3) Presentation of desired heading vs actual heading 4) Projection of vehicle movement with trial commands (path prediction)	Provide real time control of LRV using Joy stick	1) Vehicle steering CMDS 2) Vehicle speed CMDS 3) Stop/go CMDS	MOC function GUID 3 0
5.3.3 MAINTAIN HIGH GAIN ANTENNA POINTED AT EARTH	Generate the necessary pointing commands to keep the Hi-gain antenna pointed at Earth so as to receive acceptable TV pictures	1) Current LRV position and heading 2) LRV attitude data 3) Antenna pointing angles 4) Lunar ephemeris data	Convert vehicle reference frame to antenna reference frame and compute pointing commands to keep antenna fixed to Earth	1) Presentation of antenna position and vehicle attitude relative to Earth	Monitor computer program output and display to insure pointing commands are valid	1) Hi-gain antenna pointing center CMDS	MOC function GUID 7 0

TRAVERSE MODE (contd)/ DETERMINE TRACK STATUS OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5.4.1 CALCULATE VEHICLE POSITION AND HEADING (DEAD RECKONING)	Process gyro and odometer data to relate current vehicle position and heading to starting point by dead reckoning techniques	1) Directional gyro data 2) Odometer data 3) Update station fix data 4) LRV attitude data	Compute current position and heading by processing LRV heading, odometer and attitude data with updated position and heading information from navigation fix	1) A display with the plot of LRV vector movements along traverse from last update point, the planned course and the planned target site 2) X-Y plot of actual elevation changes with distance along the traverse from last update point (N-S and E-W slices)	Assess display to insure LRV computed position and heading are consistent with desired course	1) Dead reckoning position and heading data	MOC function NAV 2.0
5.4 2 MONITOR TRACK TO DETERMINE ARRIVAL AT TARGET OR IF OFF-COURSE LIMITS ARE EXCEEDED	Monitor LRV track and advise operator/driver as to track status Indicate when LRV arrives at designated stop point or if vehicle is exceeding track limits set by operation policy	1) Actual elevation vs distance from last stop 2) Predicted elevation vs distance from last stop 3) Dead reckoning position and heading data 4) Selected heading and step distance 5) Selected station stop 6) Navigation guidelines		Same as 5 3 1 but with superimposed guidelines to indicate acceptable deviations from established course	Monitor traverse and make decisions on acceptable progress of LRV	1) Off course alarm 2) Arrival at target indication 3) Course revision required	MOC function Nav 5.0

TRAVERSE MODE (contd)/ DETERMINE COURSE STATUS (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
5.4 3 DETECT OBSTACLES WHICH AFFECT VEHICLE MOBILITY	Evaluate TV pictures and tactile sensor data to detect presence of obstacles which can impede or impair vehicle Provide advisory information on nature, extent and magnitude of obstacle	1) TV pictures and related directions 2) Lunar maps 3) Tactile sensor data 4) Vehicle mobility 5) Vehicle attitude data	Process sensor data to extract information which may indicate presence of a hazardous condition beyond the limits of LRV design criteria	1) Video display of TV pictures 2) Same as 5 3 1	Provide the evaluation and assessment of the data to detect obstacles	1) Obstacle information - direction nature, extent, and magnitude (threat to vehicle)	MOC function Guid 1 0
5 4 4 DEVISE OBSTACLE AVOIDANCE MANEUVER	Evaluate obstacle information and determine optimum way of negotiating obstacle with regard to reaching desired target stop and inherent LRV mobility characteristics	1) Obstacle information 2) Selected target site 3) Lunar maps 4) TV pictures 5) Planned course 6) Actual traverse	1) Same as 5 3 3	1) Same as 5 3 3	Evaluate inputs to determine course of action to be taken	1) Heading, speed, distance corrections 2) Method to utilize LRV obstacle negotiation equipment	MOC function Guid 2 0A
Exit from 5 4 to 5.3 if LRV is off course, to 5 2 ENTRY B at arrival at planned station stop, to 5 2 ENTRY C if off course status exceeds limits, to 5 2 ENTRY D if planned target site not accessible by planned traverse, to end 5 0 at arrival at planned target site							

S. QUIESCENT MODE (6.0)

1. Objective.

The objective of this sequence is to restrict vehicle operations due to power or thermal limitations in order to:

(1) Restore battery charge to the desired level required for planned subsequent vehicle operations, or;

(2) Provide vehicle thermal control.

2. Scope

It is assumed that battery charging and thermal control functions are in continuous operation; however, the Quiescent Mode has been designated to specifically provide sequences of reduced vehicle operations for power and thermal control when vehicle limitations are reached or it is desirable to maximize the battery charge rate.

3. Assumption

The battery charge remaining has approached level requiring recharge or vehicle thermal levels require reduced operations.

4. Discussion

This mode (Fig. 39) is associated with providing for those operations required for rapid battery charging and efficient thermal control. In most cases the vehicle will be entirely shut down, except for battery charging circuits during charge periods. It is assumed that rapid battery charge will be required only when the battery discharge reaches 35% from full charge. At this time it is difficult to estimate how often this charge requirement will occur, however, an estimate can be made of the length of time required for recharging from the parameters listed below

(1) Assuming a battery capacity of 4.3 KWH X 35%, the battery charge requirement is 1.5KW.

(2) Engineering interrogation power.

(3) Total charge requirement;

Sum (1) and (2)	=	1,527 Watts
Assumed RTG output	=	130 Watts/hr
Sum RTG	=	12 Hours

Admittedly the above is a simplistic approach to the charge problem, however, within our ability to define the system design it does provide an answer satisfactory for preliminary mission planning purposes, therefore, the Quiescent Mode is assumed to last approximately 12 hours for battery charging purposes.

For planning purposes, it is assumed that heat absorption is the constraining thermal problem and that problems from cold will be solved with electric or nuclear heaters as appropriate. From a heat dissipation standpoint, the high noon solar aspect would appear to be the most critical and is considered the constraining period. It is assumed, for planning purposes, that this thermally critical period will be approximately one earth day or 24 hours in duration so that the Quiescent Mode, for thermal purposes, will last approximately 24 hours. This is consistent with Surveyor spacecraft experience.

It is conceivable that some science may be accomplished during the thermally critical Quiescent Mode. This, of course, would be limited by the down link or data storage configuration which would permit data transmission or accumulation. It is doubtful whether science could be accomplished during the battery charge periods due to the desirability of maximizing the battery charge rate.

These questions; however, require further detailed study when the vehicle configuration and thermal constraints are more fully understood.

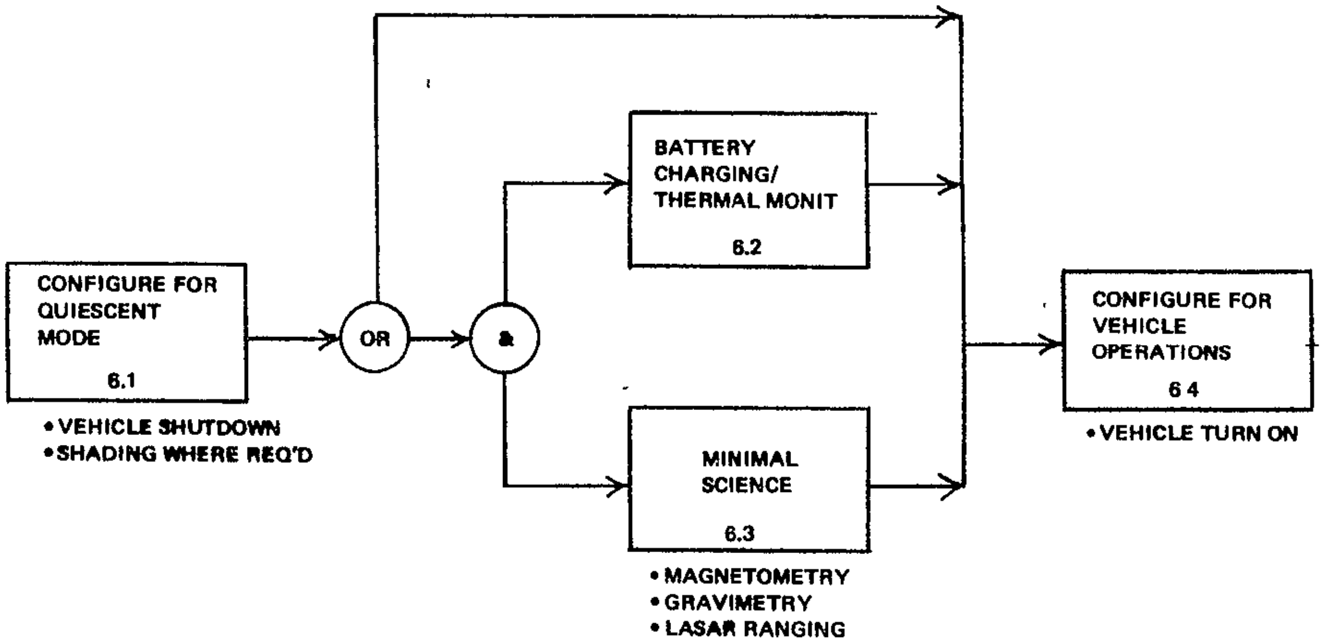


Fig. 39. Quiescent Mode - Major Sequences (6.0)

6 0 QUIESCENT MODE OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
6 1 CONFIGURE FOR QUIESCENT MODE	Select and establish LRV load configuration and LRV orientation to maintain power and/or thermal control	Power and thermal profiles to present	Vehicle TM and DSN status	• Vehicle TM • Vehicle status/ load configuration • Power and thermal profiles to present	• Review displayed information • Provide operations plan for duration of mode • Select new LRV load configuration vs time as required and new vehicle orientation as required		Vehicle downlink may be shut down for extended period to minimize energy dissipation Selection of vehicle configuration may be accomplished prior to entry mode
		• LRV load status vs time (extrapolated) • Recommended vehicle orientation	• Generate predicted power and thermal profiles	• Predicted power and thermal profiles	• Verify validity of predicted profiles	• Commands to orient vehicle as desired • Establish desired LRV load configuration	
6 2 BATTERY CHARGING/ THERMAL MONITORING	Monitor power and thermal parameters	• Battery state-of-charge status • Charge objectives • Predicted profiles from 6 1 • Thermal objectives	• Vehicle power and thermal telemetry data • Generation of actual profiles to the present • Extrapolation of actual profiles	• Vehicle power and thermal parameters • Actual profiles and their extrapolation superimposed on originally predicted profiles from 6 1	• Monitor power and thermal data for proper execution of mode • Institute downlink turn-on cycling plan as required to provide periodic data monitoring	• Uplink turn on/ off commands for 1) Refinement of load configuration vs time, and 2) Periodic monitoring of telemetry	Downlink may be shut down to maximize charge rate Periodic turn-ons of downlink will be accomplished to monitor data

6.0 QUIESCENT MODE (contd), OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
6.3 MINIMAL SCIENCE	Provide minimal scientific experimentation consistent with overall objectives of mode	• Science objectives • Science data	• Reference appropriate mode 1.0 activities	• Reference appropriate mode 1.0 activities	• Reference mode 1.0	• Reference mode 1.0	• Only low energy dissipation expr will be possible i.e., • Magnetometry • Earth distance ranging • Continuous downlink data may not be available
6.4 CONFIGURATION FOR VEHICLE OPERATIONS	Energize vehicle subsystems consistent with planned activities to follow	• Present vehicle configuration • Desired vehicle configuration	• Vehicle telemetry • DSN status	• Vehicle telemetry • Vehicle status/configuration	• Execute vehicle turn-on sequence	• Uplink turn-on commands	

T. ACTIVE SEISMIC MODE (8. 0).

1. Objective.

The objective of this mode is to establish the depth, boundaries, and seismic properties of the lunar regolith and subsurface at selected points along the traverse.

2. Scope.

It includes all activities, including site selection and site preparation, for seismic charge emplacement, seismic sensor emplacement, detonation of charge, seismic recording, and sensor storage.

3. Assumption.

(1) Each active seismic investigation may involve the detonation of a number of seismic charges but only one sensor.

(2) Seismic recording will be initiated prior to detonation and continued until subsidence has occurred.

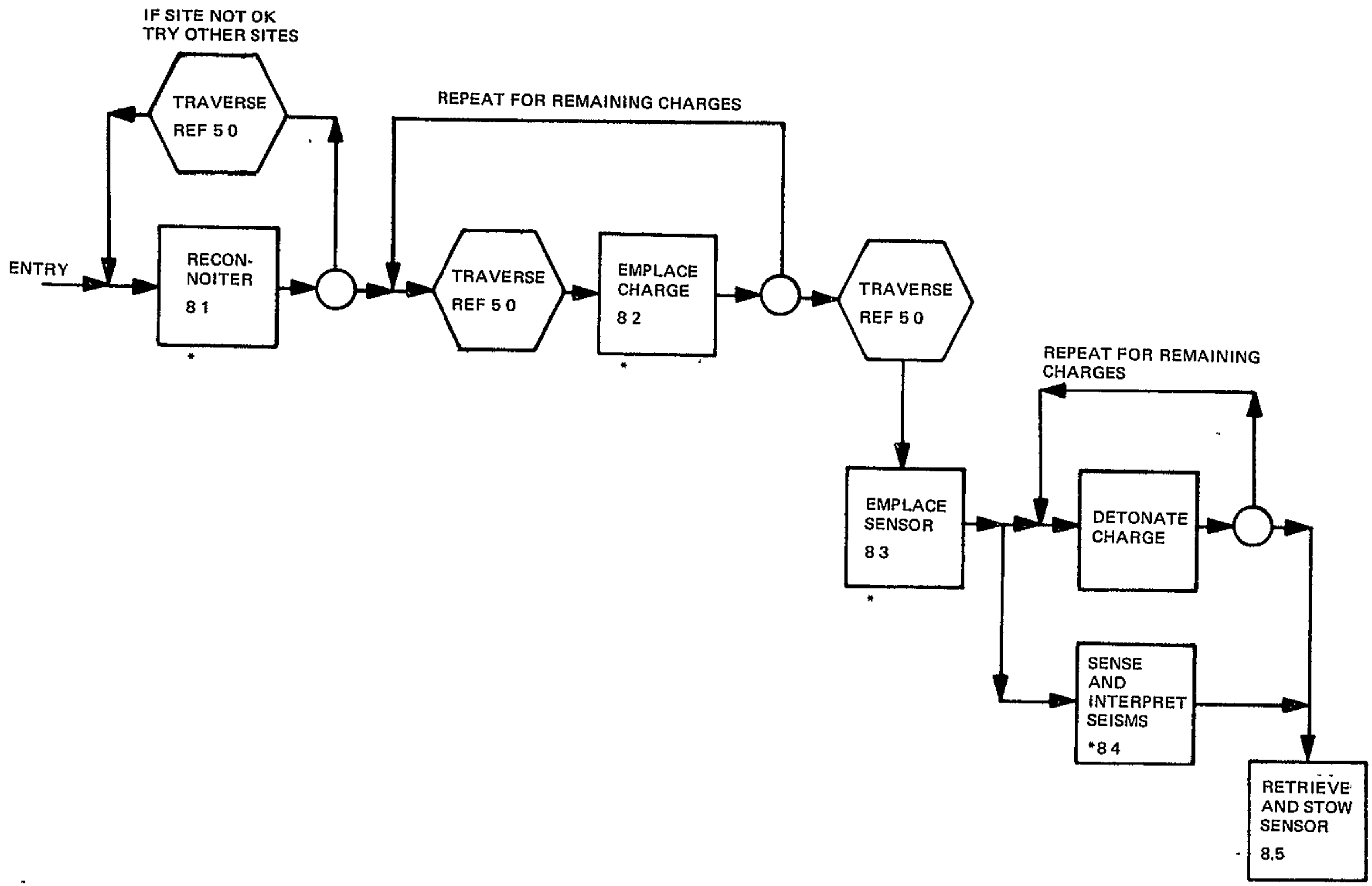
(3) Seismic waves will be sensed, recorded, and transmitted to earth.

(4) Seismic velocities in the lunar material will be determined locally at each site.

(5) Charges and sensors will be placed by means of the manipulator.

4. Discussion.

This activity (Fig. 40) includes examination of the site with the panoramic Fax camera, mapping and placing seismic charges, placing the seismic sensor, and detonation of buried seismic charges. The mode is reentrant, since traverses (Mode 5. 0) will normally be required between charge emplacement and sensor deployment.



*Further Breakdown Provided

Figure 40. Mode 8.0 Active Seismic

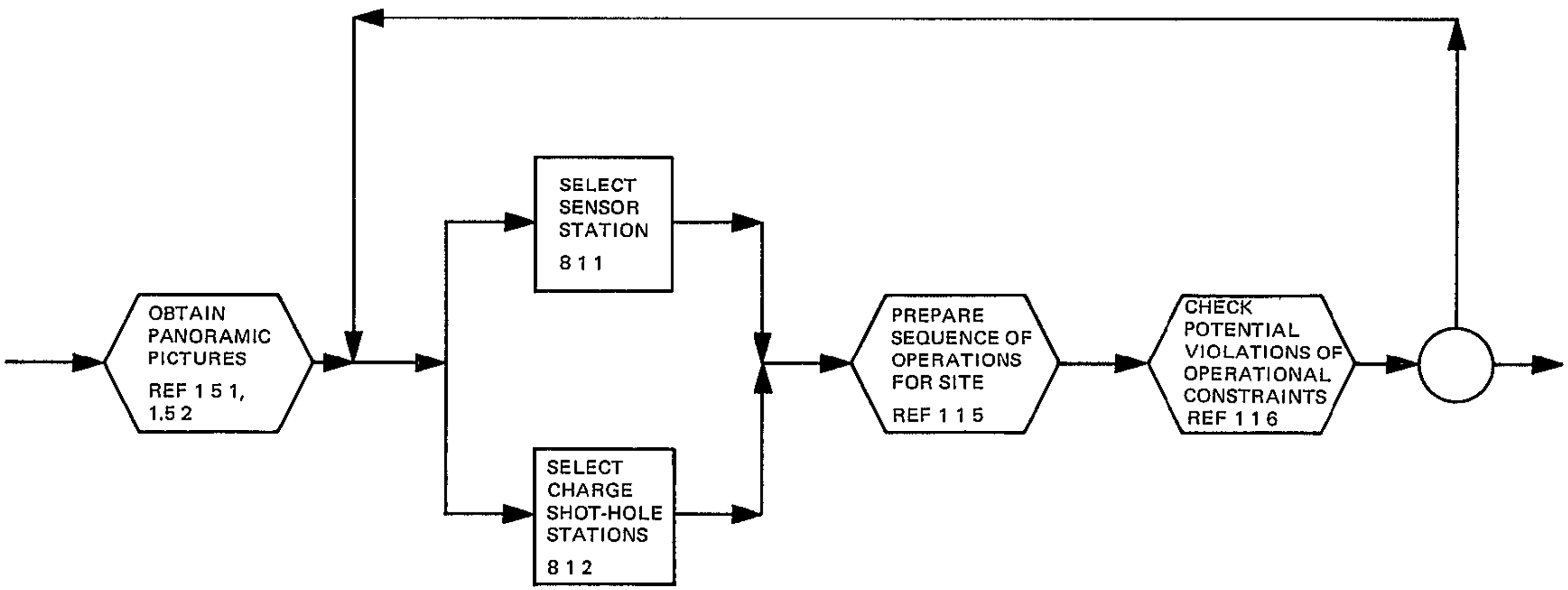


Figure 41. Major Sequence 8.1 Reconnoiter

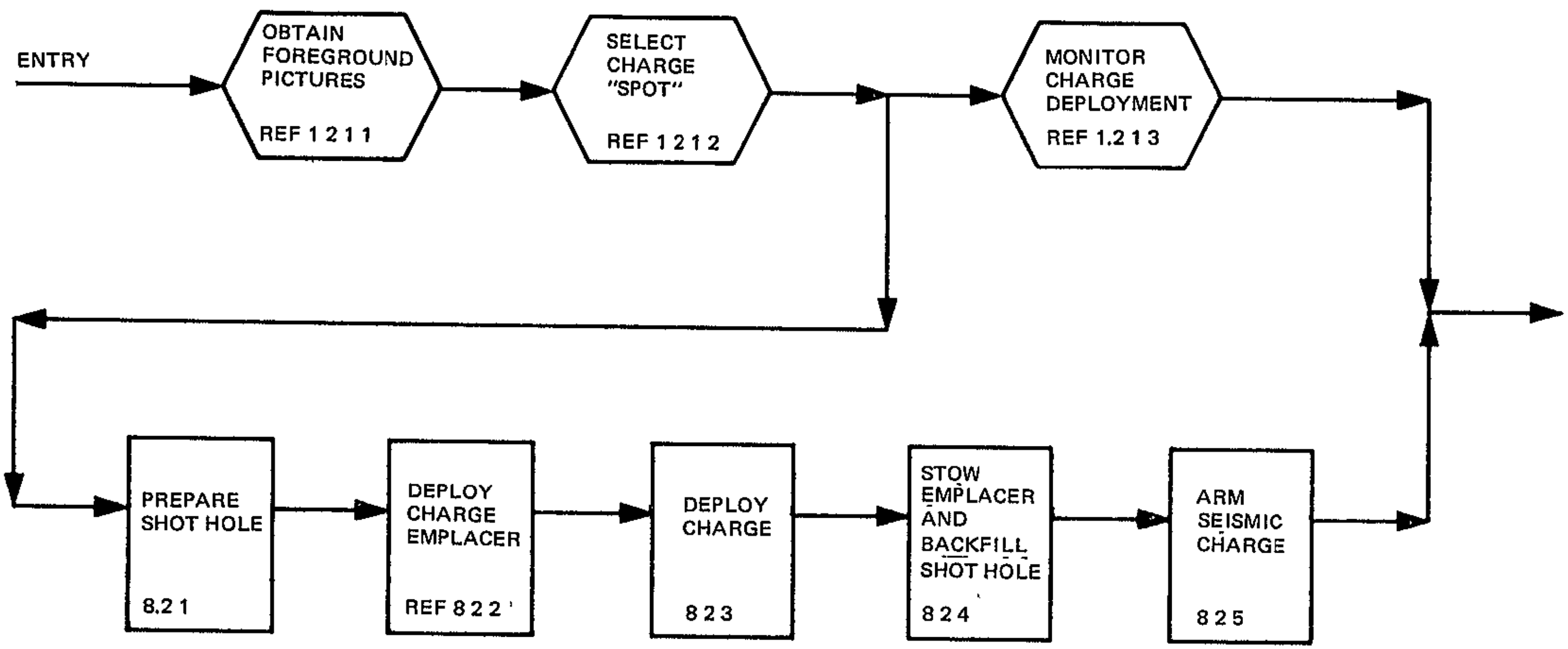


Figure 42. Major Sequence 8.2 Emplace (Seismic) Charge

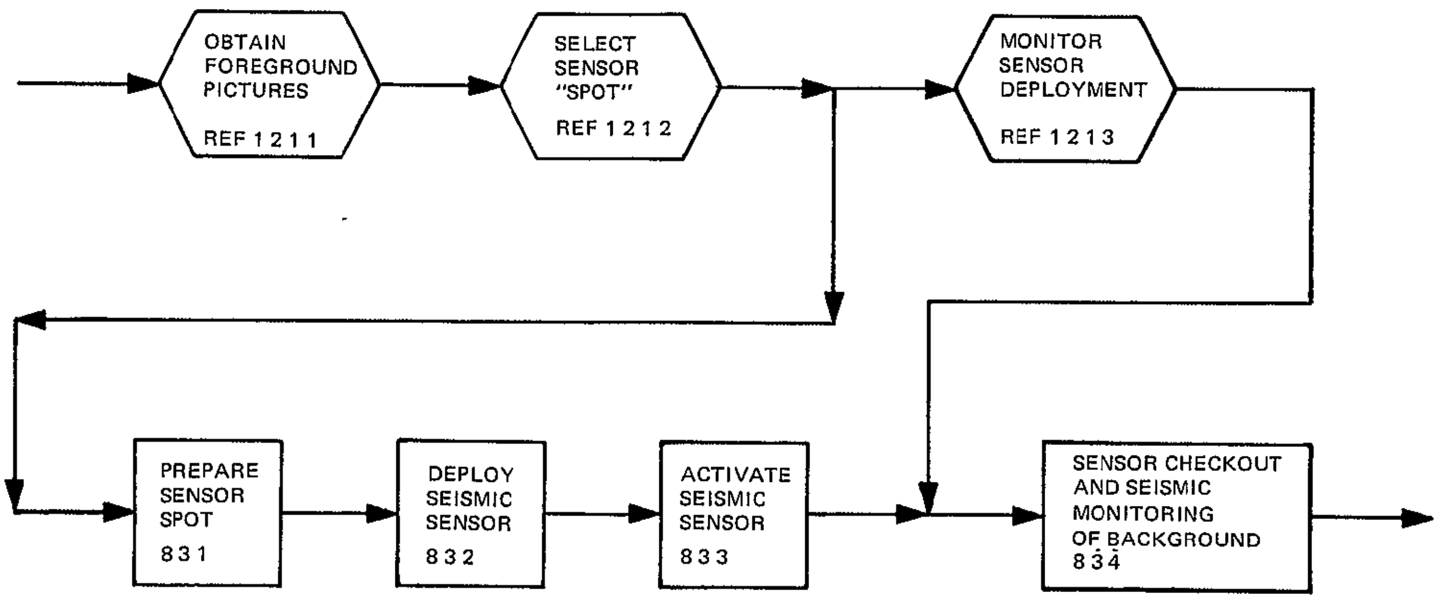


Figure 43. Major Sequence 8.3 Emplace (Seismic) Sensor

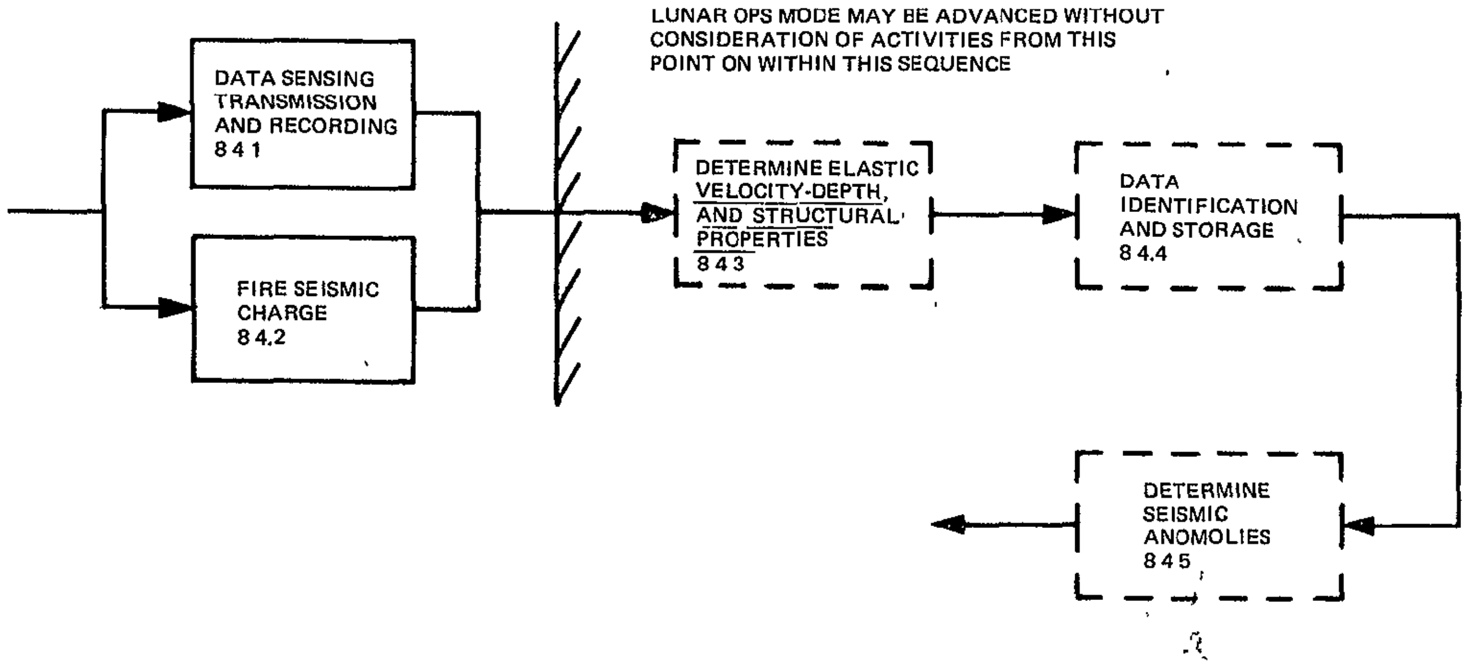


Figure 44. Major Sequence 8.4 Sense and Interpret Seismic Data

8 0 ACTIVE SEISMIC MODE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
8 1 RECONNAISSANCE 8.1 1 PROVIDE SEISMIC PLAN 8 1 1 1 SELECT SENSOR STATION	Review PAN from 1 5 1 etc (preceding) Select station suitable for execution of 8.3 & 8.4	• Panorama • Lunar OPS plan • Seismic instrument characteristics	• Determine local coordinates of selected station • Identify line-of-sight from recon station (AZ∢) for subsequent display	• Panorama and selected station and assoc local coordinates • Line-of-sight to selected station	• Analyze Panorama for optimum positioning of sensor station	• Coordinates of sensor station given to NAV/GUID OPS for determination of future LRV repositioning OPS	
8 1 1 2 PREPARE CHARGE DEPLOYMENT PATTERN	Review PAN from 1 5.1 etc (preceding) Select station suitable for execution of 8.2 and 8.4	• Panorama • Lunar OPS plan • Seismic instrument characteristics	• Determine local coordinates of selected station • Identify line-of-sight from recon station (AZ∢) for subsequent display	• Panorama and selected station and assoc local coordinates • Line-of-sight to selected station	• Analyze Panorama for optimum positioning of sensor station	• Coordinates of sensor station given to NAV/GUID OPS for determination of future LRV repositioning OPS	
8.2.1 PREPARE SHOT HOLE	Deploy shot hole drill mechanism	1) Drill device TM data 2) TV view of selected site and drill device	1) Convert TM data to drill device status information 2) Transform video data into TV pictures	Same as information received	Manipulate drill device through evaluation of TM data and foreground TV pictures	Drill device deployment commands	
	Drill shot hole for seismic charge	Same as 8 2 1	Same as 8 2 1	Same as 8 2 1	Same as 8.2 1	Drill device commands to drill shot hole	
	Withdraw drill from shot hole	Same as 8 2 1	Same as 8.2.1	Same as 8.2.1	Same as 8 2 1	Drill device commands to withdraw drill device from shot hole	
	Stow shot hole drill mechanism	Same as 8 2 1	Same as 8 2.1	Same as 8 2 1	Same as 8 2 1	Drill device stowage commands	

ACTIVE SEISMIC MODE (contd)/ 8.2 EMPLACE SEISMIC CHARGE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
8.2.2 DEPLOY SEISMIC CHARGE EMPLACER	Deploy seismic charge emplacer to ground	1) Seismic charge emplacer TM data 2) TV view of selected site and seismic charge emplacer	1) Convert TM data to seismic charge emplacer status information 2) Transform video data into TV pictures	Same as information received	Manipulate seismic charge emplacer through evaluation of TM data and foreground TV pictures	Seismic charge emplacer deployment commands	
8.2.3 DEPLOY SEISMIC CHARGE	Place seismic charge emplacer into shot hole	Same as 8.2.3	Same as 8.2.3	Same as 8.2.3	Same as 8.2.3	Seismic shot emplacer commands	
	Deploy seismic charge	1) TM data attendant to seismic charge 2) TV view of selected site and seismic charge	1) Convert TM data to device status information 2) Transform video data into TV pictures	Same as information received	Manipulate seismic charge through evaluation of TM data and foreground TV pictures	Seismic charge deployment commands	
8.2.4 STOW EMPLACER AND BACKFILL SHOT HOLE	Place seismic charge in seismic charge emplacer	Same as 8.2.3	Same as 8.2.3	Same as 8.2.3	Same as 8.2.3	Commands to place seismic charge into seismic charge emplacer	
	Withdraw seismic charge emplacer from shot hole	Same as 8.2.2	Same as 8.2.2	Same as 8.2.2	Same as 8.2.2	Commands to withdraw seismic charge emplacer from shot hole	
	Stow seismic charge emplacer in LRV	Same as 8.2.2	Same as 8.2.2	Same as 8.2.2	Same as 8.2.2	Seismic charge emplacer stowage commands	
	Back fill shot hole by scraping drill ejecta into it with the soil sampler	1) Soil sampler TM data 2) TV view of selected site and soil sampler	1) Convert TM data to device status information 2) Transform video data into TV pictures	Same as information received	Manipulate soil sampler through evaluation of TM data and foreground TV pictures	Soil sampler commands	

EMPLACE AND ACTIVATE SEISMIC SENSOR OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
8.2.5 ARM SEISMIC CHARGE	Arm seismic charge	1) Arming device TM data 2) TV view of selected site and arming mechanism	1) Convert TM data to arming device status information 2) Transform video data into TV pictures	Same as information received	Manipulate arming device through evaluation of TM data and foreground TV pictures	Arm seismic charge commands	
8.3.1 PREPARE SENSOR SPOT	Clear location of debris and loose soil with soil sampler	1) Soil sampler TM data 2) TV view of selected site and soil sampler	1) Convert TM data to soil sampler status information 2) Transform video data into TV pictures	Same as information received	Manipulate soil sampler through evaluation of TM data and foreground TV pictures	Soil sampler commands	
8.3.2 DEPLOY SEISMIC SENSOR	Deploy Seismic sensor to cleared location	1) Seismic sensor TM data 2) TV view of selected site and seismic sensor	1) Convert TM data to seismic sensor status information 2) Transform video data into TV pictures	Same as information received	Manipulate seismic sensor through evaluation of TM data and foreground TV pictures	Commands to place seismic sensor in cleared location	
	Press seismic sensor into position with soil sampler	Same as 8.3.1	Same as 8.3.1	Same as 8.3.1	Manipulate soil sampler through evaluation of TM data and foreground TV pictures	Soil sampler commands to press seismic sensor into position	
8.3.3 ACTIVATE SEISMIC SENSOR	Uncage seismic sensor	1) Seismic sensor transducer signal TM data 2) TV view of selected site and seismic sensor	1) Convert TM data to seismic signal information 2) Transform video data into TV pictures	Same as information received	Initiate uncaging	Commands to uncage seismic sensor	

EMPLACE AND ACTIVATE SEISMIC SENSOR (contd) OPERATIONS PROFILE	MOC PROFILE (ACTIVITIES ON THE EARTH)						
	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
8.3.4 SENSOR CHECKOUT AND SEISMIC MONITORING OF BACKGROUND	Turn off all subsystems which affect background noise level of seismic sensor output signal	1) TM data of various LRV subsystems 2) TV view of selected site and seismic sensor	1) Convert TM data to subsystem status information 2) Transform video data into TV pictures	Same as information received	Evaluate TM data to verify turn off LRV subsystems	Commands to initiate sequence(s) to turn off LRV subsystems	
	Calibrate seismic sensor	1) Seismic sensor transducer output TM data 2) TV view of selected site and seismic sensor	1) Convert TM data to seismic signal information 2) Transform video data into TV pictures	Same as information received	Evaluate signal and establish coefficients for sensor output signal conversion	1) Commands to input a known signal to the seismic sensor 2) Commands to change performance characteristics of seismic sensor, as required (E G adjust instrument damping, gain, etc)	
8.4.1 DATA SENSING, TRANSMISSION, AND RECORDING	Record seismic data	Same as 8.3 4	Same as 8.3.4	Same as 8.3 4	Monitor seismic background signal for valid data	None	
8 4 2 FIRE SEISMIC CHARGE	Fire seismic charge	Same as 8 3 4	Same as 8.3 4	Same as 8 3 4	1) Initiate seismic charge firing 2) Monitor seismic signal for receipt of detonation waves by sensor	Fire seismic charge commands	

STOW SEISMIC SENSOR	MOC PROFILE (ACTIVITIES ON THE EARTH)						
OPERATIONS PROFILE	SUMMARY MOC PROFILE	INFORMATION RECEIVED	INFORMATION PROCESSING	INFORMATION DISPLAY	HUMAN ACTIVITIES	INFORMATION TRANSMITTED	REMARKS
8.5.1 CAGE SEISMIC SENSOR	Cage seismic sensor	1) Cessation of seismic sensor transducer signal TM data 2) TV view of selected site and seismic sensor	1) Convert TM data to seismic signal information 2) Transform video data into TV pictures	Same as information received	Initiate caging	Commands to cage seismic sensor	
8 5 2 RETRIEVE AND STOW SEISMIC SENSOR	Retrieve and stow seismic sensor	Same as 8.3.2	Same as 8 3 2	Same as 8.3.2	Manipulate seismic sensor through evaluation of TM data and foreground TV pictures	Seismic sensor retrieval and stowage commands	

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The detailed conclusions reached in this study are presented throughout the body of the report in the operations profiles, as a Phase B definition of the sequence of operations and the corresponding ground system activities.

At a higher level of consideration, it is concluded from the study that:

(1) Subdivision of the total mission into its repeatable elements (operational modes) has proven to be a practicable means of preliminary mission analysis.

(2) Successful achievement of the goals of the LRV mission will require a greater degree of coordination between science experiments than has been required in previous spaceflight missions.

(3) The LRV mission would profit from a number of technological capabilities which are currently in a state of development (See paragraph B below).

B. RECOMMENDATIONS

1. Further Operations Profile Analyses

The Operations Profiles for some of the LRV operational modes identified herein have not been developed yet. In future work, these additional modes should be analyzed in the same manner as the present study. These modes fall into three general groups.

a. Night-Related Operations

These include all nighttime operations (such as steering, navigation, and science), plus the changeovers between day and night conditions. Dominant problems relate to low-light-level video and to power and thermal conditioning.

b. Equipment-Constrained Operations

The Operations Profiles associated with these modes are dependent upon the particular design of vehicular equipment. This group of modes

centers about science-package deployment, vehicle condition diagnosis, and mandatory quiescence.

c. Mode-Independent Operations

These are the operations which are not directly associated with any particular mode. The group includes continuous operational functions, mission trade-off management, and continuing data analysis.

2. Mission Analyses

Four important elements of mission operations should be analyzed as early as possible because of their impact upon the remainder of the mission.

a. Time Line Analyses.

Time line analyses estimating the time intervals required to execute operational modes would enable estimation of the total time required to execute candidate missions.

b. Video Data Transmission Rates

Video data transmission rates from the vehicle on the moon to the control center, constitute one of the principal factors pacing many of the operations.

c. Extensions of the Landmark Navigation Technique.

Extensions of the landmark navigation technique including elevation control and semi-continuous confirmation of position would improve materially the knowledge of vehicle position as it advances.

d. Remote Driving Delay Compensation.

Remote driving delay compensation offers a means of achieving reasonably stable, controlled motion of the vehicle despite local disturbing influences.

3. Technological Advances.

Current advances in the state-of-the-art in the following operations fields have been shown to be potentially beneficial to the LRV mission. The capabilities that each can be expected to provide should be evaluated.

a. Position Determination.

High precision on-board equipment to determine both absolute position on the moon and relative motion (traversing) over its surface are currently being developed.

b. Earth-Based Tracking.

High precision ranging equipment, both laser and very-long based radio interferometry, capable of determining the position of the vehicle with respect to the moon, are under study.

c. Low-Light-Level TV.

Television systems capable of permitting lunar nighttime imaging operations have been demonstrated.

d. Laser Radar

Ranging systems to non-cooperative targets, capable of determining the geometric relation of terrain features to the vehicle, are under development.

e. Laser Holography

Three dimensional imaging by holography has been demonstrated very successfully on earth; the technique may possible yield benefits when extended to remote operations on the moon.

APPENDIX A

I. REFERENCES

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2. Hornbrook, G. K., LRV Navigation and Guidance System Phase A Study Report, Document 760-42. Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1969.

3. McCormick, C. W. B., Science Ground Data System and Science Operations Organization for Remotely Controlled Lunar Traverses; Phase A Study Report. Oct. 10, 1969.

4. Final Report, Dual-Mode Manned/Automated Lunar Roving Vehicle, Design Definition Study, Report BSR 2816. Bendix Corporation, Jan., 1970.

5. Dual-Mode Lunar Roving Vehicle, Preliminary Design Study; Final Report. Grumman Aerospace Corporation, Feb. 1970.

APPENDIX B. NOMENCLATURE

I. DEFINITIONS

Anomaly	- A significant deviation of the current data from previous norms.
Celestial Navigation	- Determination of (selenographic) position and heading from the apparent position of heavenly bodies.
Course	- Planned path of travel.
Guidance	- Total of all functions necessary for safe execution of course.
Hazard	- A condition inimical to success of the mission.
Heading	- Direction of pointing of forward end of vehicle axis.
Landmark	- Unique features of the terrain which can be identified positively, both on the map and in the field.
Landmark Navigation	- Determination of (selenographic) position and heading from field observation of landmarks.
Management Control Functions	- Direction of the use of mission resources to maximize the achievement of mission objectives.
Mission Operations Plan	- Document describing intended operations of the mission, including operations, organizations, equipment, procedures, time schedules, path, and conditions.
Navigation	- Total of all functions necessary to determine track and course.
Navigation Update	- Direct measurement of (selenographic) position independently of dead reckoning.
Non-Real Time Operations	- Earth-based operations which may be performed independently of the operations mode which prevails.
Obstacle	- A physical feature obstructing travel.
Operational Mode	- Standardized sequence of operations needed to accomplish a particular class of objectives.
Operations Profile	- The set of all real-time activities on earth, needed to accomplish the mission.

Point	- A particular location (for sampling, deployment, etc.).
Real-Time Operations	- Earth-based operations which must be performed sufficiently rapidly to preclude operational delays.
Site	- Area containing all activities involved within a single Stationary Science Mode.
Spot	- Same as "Point".
Standoff Position	- Position in front of target from which final approach can be made under human control.
Station	- Position of vehicle when stopped.
Target	- Intended position.
Track	- Actual path of travel.
Traverse	- Total path of the vehicle. Traverses may be planned traverses or actual traverses.

II. ACRONYMS AND ABBREVIATIONS

ALSEP	APOLLO Lunar Surface Exploration Package
AMS	Atmospheric Mass Spectrometer
CC&S	Central Computer and Sequencer
CMD	Command
CO	Checkout
CTL	Control
DLRV	Dual-Mode Lunar Roving Vehicle
FAX	Facsimile Camera
GDS	Ground Data System
GRAV	Gravimeter
INST	Instrument
LRV	Lunar Roving Vehicle
MC	Motion Control
MOC	Mission Operations Complex
MOP	Mission Operations Plan
NG	Navigation and Guidance
NGTP	Navigation/Guidance Instrument Package
NGRA	Neutron Gamma-Ray Analyzer
OPS	Operations
PAN	Panoramic
PWR	Power System
RECON	Reconnoiter
REQD	Required
RGM	Remote Geophysical Monitor
SEQ	Sequence

SOE	Sequence of Events
TA	Terrain Assessment Camera
TM	Telemetry
TODS	Tactile Obstacle Detection System
TV	Television
XMIT	Transmit
XRD	X-Ray Diffractometer
XRS	X-Ray Spectrometer
CALC	Calculate
CHAR	Characteristics
DET	Detect
DWN	Down
INST	Instrument
MAG	Magnetometer
MECH	Mechanism
N/G NAV/GUID	Navigation/Guidance
PLN	Plan
POS	Position
RQMTS	Requirements
TAB	Tabulate

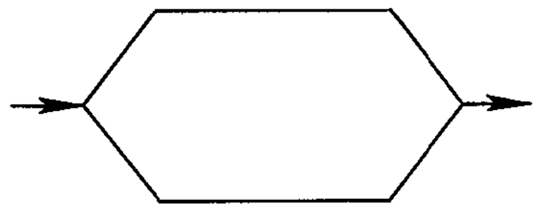
APPENDIX C

CHART SYMBOLS

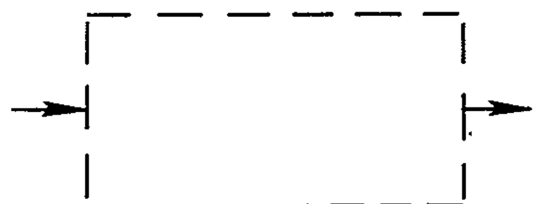
Unit Operations

First appearance in charts

Back reference to earlier description

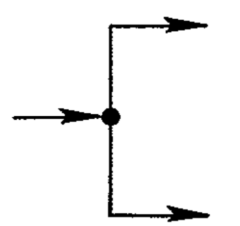


Non-real time execution

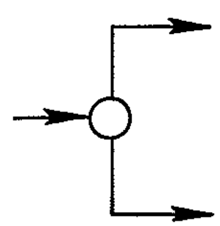


Path Divisions

Concurrent (both paths)



OR-Gate (on path only)



APPENDIX D. SCIENCE UPDATE

The following instruments in the science payload assumed in this report (see Table 4) have been added since the publication of Ref. 3. Their purpose and functions are described below.

I. GENERAL PURPOSE MANIPULATOR

A. Purpose

The purpose of the General Purpose Manipulator is to provide remotely-controlled displacement (both translational and rotational) relative to the vehicle frame for a specified set of (end) tools with capability for the tools to function at all articulations.

B. Functions

1. To hold any (one) selected tool of the set of tools.
2. To grasp and release such tools.
3. To store and retrieve such tools on the vehicle.
4. To secure (latch) grasped tools to ensure against accidental loss of a grasped specimen.
5. To deliver any one tool automatically to any specified spatial position within the proper domain of the manipulator.
6. To support the functioning of any grasped tool at any articulative position of the manipulator.
7. To prevent interference of manipulator and tool with vehicle parts during automatic deployment.

II SAMPLE CUP HOLDER

A. Purpose

The purpose of the Sample Cup Holder is to provide a soil-sample acquisition device with reasonably reliable protection against cross-contamination between successive samples.

B. Functions

1. To provide structural support for a soil-sample cup during the period that the cup is used to excavate samples from loose soil.
2. To transport the sample cup between the sampling system and the sample acquisition point.
3. To transfer the cup, when loaded, to the sample storage system.
4. To jettison the cup, upon command.

III. ATMOSPHERIC MASS SPECTROMETER

A. Purpose

1. To determine the identity and abundance of particles constituting the lunar atmosphere.
2. To measure the time-wise change in identity and abundance of particles during the sunrise and sunset periods.
3. To measure space-wise changes in identity and abundance of particles and to correlate these with surface features.

B. Functions

1. To acquire, upon command, a sample of the atmosphere surrounding the vehicle.
2. To analyze the particles in the atmosphere-sample as to chemical composition and abundance.
3. To make the results of the foregoing analyses available.

IV NEUTRON GAMMA RAY ANALYZER (NGRA)

A. Purpose

1. To analyze the composition of the lunar material to a depth of tens of centimeters.
2. To determine the moisture content of the lunar material down to a depth of tens of centimeters.
3. To determine the bulk density of the lunar material in the top tens of centimeters.

4

B. Functions

1. To measure the natural (unstimulated) emission of radiation from the subject material.
2. To irradiate the subject material in order to stimulate its radiation.
3. To measure the magnitude and character of the augmented radiation in response to external stimulation.

V. LASER RADAR (Scanning Laser Range Finder)

A. Purpose

1. For guidance applications, the purpose of laser radar is to detect, locate, and evaluate obstacles in the path of the vehicle.
2. For navigation applications, the purpose of laser radar is to determine, to high accuracy, the position of the vehicle with respect to landmarks which appear on both the visible terrain and the reference maps.
3. For science applications, the purpose of laser radar is to determine the shape and reflectivity of the ground surface.

B. Functions

1. To measure the line-of-sight distance from the observer to selected reflecting points.
2. To measure the ratio of the strengths of the return and transmitted signals, for use in the earth-based estimation of the subject's albedo.
3. To repeat the above observations, upon command, in an image-scanning mode.